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THEORETICAL FUNDAMENTALS AND APPLIED ASPECTS OF THE FINAL DEVELOPMENT STAGE OF HYDROCARBON RESERVOIRS, IMPROVING OF METHODS FOR ENHANCING THEIR COMPONENT RECOVERY (BASED ON GASCONDENSATE FIELDS OF AZERBAIJAN)

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THESIS ABSTRACT

of the dissertation work submitted for the degree of

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AZƏRBAYCAN RESPUBLİKASI ELM VƏ TƏHSİL NAZİRLİYİ "AZƏRBAYCAN DÖVLƏT NEFT VƏ SƏNAYE UNİVERSİTETİ" PUBLİK HÜQUQİ ŞƏXS

GENERAL DESCRIPTION OF WORK

The topicality and development degree of the subject.

The underperformance of water injection, which is one of the conventional methods to maintain reservoir energy, and the fact that the gas injection method requires a large number of surface equipment, especially increases the advantage of natural operation of gas condensate fields with high gas factor, layer temperature and pressure. However, a series of challenges arising in the course of the operation of the field due to natural energy increase the unrecoverable volume of the hydrocarbon condensate, which is of vital industrial importance, and also sharply increases the cost of the measures applied at the final stage. Therefore, the proper assessment of the initial state of the given field, the optimal development system, the current thermodynamic state of operation and the third type stimulation methods on the field are vitally important issues. Thus, the scientific justification of the project to be accepted is largely dependent on comprehensive knowledge and full-fledged research data. In this case, the study of the phase transformations of the reservoir system during operation and the appropriate compiling of the phase diagram are considered important issues.

It is, however, clear that the layer systems have a very complex structures, and studying the phase relations of such systems in complex thermobaric conditions becomes even more complicated. In order to develop optimized mathematical and thermodynamic models in such studies, the lithological composition of the formation rocks, the amount of residual water in the formation, the group composition of the formation system, the amount of non-hydrocarbon components and other factors should be taken into account. Considering such factors should theoretically help to increase the accuracy of the determined model, but the diversity of the influencing factors complicates the studies in such a way that it becomes impossible to conduct deterministic analyses and test the model. In such cases, there is a greater need for experimental studies. These problems include building more reliable laboratory facilities, creating the right methodology for conducting experimental tests, and justifying the compatibility of the obtained results with natural processes.

The above confirms that the scientific directions studied in the dissertation work are among the actual issues in the more efficient development of gas condensate fields. Providing solutions to these scientific issues is of vital importance in working out the rational processing methods of deposits and enhancing hydrocarbon recovery.

The object and subject of the research

1. Development of effective methods to enhance the final condensate recovery from formations in the course of operating gas condensate fields in the modes of depletion and full or partial maintenance of formation pressure.
2. Increasing the reliability of the methods of physical modeling of gas condensate systems in PVT bomb and porous medium conditions.
3. Determination of similarity (compatibility) criteria and their automodel areas in order to create real models of the processes observed during the development of gas condensate fields.
4. Optimization of operation of gas condensate deposits by the method of full or partial maintenance of formation pressure in accordance with thermobaric conditions and determining the requirements for the working agent.
5. Increasing the efficiency of field development by stimulating the hydrocarbon condensate deposited in the layer in various stages of development by complex methods.

Purpose and objectives of research

The main goal of the dissertation work is to discover the complications that arise in the gas condensate fields operated in the depletion mode, to study their physico-chemical and thermodynamic essence, to improve the existing development methods and to create more efficient methods that enable the extraction of residual natural resources remaining in the field at the last stage of exploitation.

Research methods. The study of the phase transformations occurring in the gas condensate systems during the operation of the fields was carried out in the PVT bomb and reservoir model by conventional differential and contact isotherm methods.

Gas and liquid chromatography and standard devices were used to determine the physico-thermodynamic properties of the reservoir system. At the last stage of the development of gas condensate deposits in the depletion mode, special statistical analyzes were carried out and similarity criteria were determined for modeling the processes of production of retrograde deposited condensate by various methods.

In order to optimize the number of experiments to be conducted and to increase the reliability of the obtained correlations, statistical methods such as rational planning of experiments and combination squares were applied. At the same time, statistical analyzes and special computer programs were used in the analysis of the results and in making mathematical calculations.

Provisions for defense

1. Identifying and eliminating shortcomings of experimental research methods of phase transformations of gas condensate systems and creating optimized methods;
2. Processes accompanied with a decrease in pressure in gas condensate fields developed by natural energy, their physical-thermodynamic nature, classification and ways of elimination;
3. Increasing the efficiency of gas condensate deposits by optimizing the methods of operating them in the mode of partial maintenance of reservoir energy by injecting gas;
4. Physical-thermodynamic basis and development of existing methods of production of retrograde condensate deposited in the well bottom zone during recovery of gas condensate fields in depletion mode;
5. Optimization of production methods by dispersing retrograde deposited condensate in the gas phase in gas condensate fields operated in depletion mode;
6. Development of a new method of production of retrograde deposited and hard-to-recover condensate remaining in the formation at the last stage of development in mature gas condensate fields.

Scientific novelty of the research

- In order to fully reflect the processes occurring in the layer during the study of phase transformations of gas-condensate systems in the physical layer model, the criteria of similarity were determined and automodel areas were determined for various research methods;
- The physical-thermodynamic nature of complications arising during the operation of gas condensate fields in the depletion mode is explained, classified and ways of their elimination are introduced;
- In order to increase the efficiency of the process of fully or partially maintaining reservoir energy by injecting gas during the development of gas condensate fields, the ways of managing the leading parameters and the requirements defined for the working agent have been determined;
- Ways to optimize the methods of recovering the liquid condensate remaining in the bottom zone during the operation of gas condensate deposits in the depletion mode and the criteria of the methods of stimulating the formation, taking into account the impact of various factors, have been determined;
- The mechanism of the influence of gases of different composition on the process of dispersing the condensate deposited in the layer was investigated, the methods of producing condensate with the management of gas-liquid phase relations were improved;
- At the final stage of the development, a new method was developed for displacing and recovering the condensate deposited in the formation into production wells.

Theoretical and practical significance of the research

The subject brought up in the research work are devoted to the study of complex phase transformations that occur during the exploitation of gas condensate fields in the depletion mode, to the optimization of existing methods for eliminating the aftereffects caused by this mode, and to the development of more efficient methods. In this sense, the results provided in the dissertation are of high empirical importance. The methods and results proposed in the dissertation have been successfully used in the following scientific-research works carried out at ANAS Institute of “Geology and

Geophysics”, and “Oil and Gas” Institute and SOCAR "OilGasScientificResearchProject" Institute, and the results have been applied in production:

1. In 2001-2002, "Thermodynamic and physico-chemical study of product samples of gas condensate wells" for "Bulla-deniz" field, carried out by the order of SOCAR Offshore Oil and Gas Production Unit;

2. In 2010-2011, "Development of an automated database on the thermodynamic and physico-chemical properties of the fluids of deeply located gas-condensate deposits in Azerbaijan" for "Bahar" and "Bulla-deniz" fields, carried out by Azneft PU in 2010-2011;

3. Experimental study of the physico-chemical and thermodynamic properties of the product of gas-condensate wells of "Balakhani" Formation of "Gunashli" field, carried out by the order of Azneft PU in 2008-2009";

4. Prediction of development indicators of V and VII horizons on the basis of geological and hydrodynamic modeling of the "Umid" field carried out by the order of Azneft PU in 2013-2014";

5. In 2015, commissioned by SOCAR, "Development plan of gas condensate and oil facilities lying deep in Azeri-Chirag-Deep Water Guneshli fields";

6. Construction of geological and hydrodynamic models of "Bulla-deniz" field, carried out by the order of Azneft PU in 2017-2019";

7. In 2018-2019, "Selection of formation stimulation methods and evaluation of their effectiveness while maintaining the pace of development on the basis of geological and hydrodynamic modeling of West Absheron field" was carried out by the order of Azneft PU in 2018-2019;

8. In 2019-2020, "The role of fluid composition in phase transformations during the development of gas-condensate fields and the effect on component yield of the field" performed under the 15TR-19LR contract within the framework of the Grant Project allocated by the "Partner Science Development Support" Public Union and 2021-2022 "Ways of enhancing the productivity of gas

condensate fields operated in depletion mode, taking into account the characteristics of layer systems", executed under contract 14TR-21LR.

In addition, the test works conducted for the production of retrograde condensate in the gas condensate wells belonging to the Bulla daniz field proved the perspective of the new results presented by the dissertation work.

Approbation and application of work

The main provisions on the content of the dissertation were discussed at the following international scientific conferences and forums:

- International Conference on Fluid and Thermal Energy Conversion (Bandung, Java, Indonesia. 2-6 July 2000);
- International scientific and practical conference, "Boundary problems of aerohydromechanics and their applications" dedicated to the 90th anniversary of the birth of G.G. Tumashev (Kazan, November 21-24, 2000);
- "Modern problems of informatization, cybernetics and information technologies" Republican scientific conference (Baku, April 28-30, 2003);
- "Khazarneftgasyatag-2004" Scientific-experimental Conference (Baku, October 24-26, 2004);
- International conference, "Fundamental problems of development of oil and gas deposits, production and transportation of hydrocarbon raw materials" (Moscow, November 24-26, 2004);
- IX International Energy Forum, "Gas and oil CIS", (Yalta, September 14-16, 2006);
- SPE, "Russian Oil and Gas Technical Conference and Exhibition" (Moscow, October 3-6, 2006);
- SPE Romanian Conference "150 Years of the Romanian Petroleum Industry Tradition and Challenges" (Bucharest, October 14-17, 2007);
- International scientific and practical conference dedicated to the 30th anniversary of the Atyrau Institute of Oil and Gas (Atyrau, September 30 - October 1, 2010);
- International scientific and practical conference "Modern

problems of the oil and gas complex of Kazakhstan" (Aktau, February 23-25, 2011);

- International scientific and practical conference "New technologies in oil and gas production" (Baku, September 6-7, 2012);
- XI International scientific and practical oil and gas conference (Kislovodsk, October 27-31, 2014);
- "Modern methods of field development with hard-to-recover reserves and unconventional reservoirs" (Atyrau, September 5-6, 2019);
- IV International scientific-practical conference "Bulatov readings" (Krasnodar, March 31, 2020);
- International conference "Innovative approaches to the development of the educational and production cluster in the oil and gas industry" (Tashkent, April 30, 2022);
- At the Scientific Council of the Institute of Geology and Geophysics of ANAS and in the section "Development and exploitation of oil and gas fields", mobile seminars and conferences of "Oilgasscientificresearchproject" Institute of SOCAR, as well as "Development and development of oil and gas fields, transportation of oil and gas and drilling of wells" In the Academic Council section.

Three of the main results obtained in the dissertation were included in the "70th Anniversary of ANAS" report (2015), and some were included in the list of the most important results of ANAS in 2004, 2006, 2008, 2010, 2014, 2015 and 2016.

Testing of new results and methods was carried out in Bulla-daniz and Bahar gas condensate fields and gas condensate horizons located deep in Gunashli field.

Published papers

The main content of the dissertation was published in 58 scientific works, including 1 monograph, 42 articles and 15 conference materials.

The organization where the dissertation work was performed. The dissertation work was carried out at the "Geology and Geophysics" and "Oil and Gas" Institutes of Azerbaijan National Academy of Sciences (ANAS).

The total volume of the dissertation with a sign, indicating the volume of the structural units of the dissertation separately.

The dissertation consists of an introduction, 5 chapters, a conclusion, a list of 344 references and appendices. The total volume of the work is 312 pages, including 76 figures, 20 tables, bibliography and appendices.

The volume of the dissertation work: introduction 15642 symbols, Chapter I 66178 symbols, Chapter II 98363 symbols, Chapter III 60797 symbols, Chapter IV 105228 symbols, Chapter V 37277 symbols, Conclusion and proposals consist are 8255 signs and total 391740 signs.

Personal contribution by the author. The author directly participated in the planning of the scientific research presented in the dissertation, setting the issues, choosing the research methods, creating the experimental device and conducting the laboratory research. He led the selection of the topics of all published scientific works and reports covering the subject of the dissertation, justification, creation of research methodology, summaries of scientific literature and analysis of results.

The author was also the responsible executor or leader of the scientific research works and economic accounting works performed at the Institute of Geology and Geophysics of ANAS and at the SOCAR "Oil and Gas Research Project" Institute, which formed the content of the dissertation work.

The author remembers with deep gratitude the late academician M.T.Abasov, who supported and guided him at all stages of the work, and the late professor Z.Y.Abbasov, his scientific advisor, corresponding member of ANAS, who worked hard on the completion of the work.

At the same time, the author thanks the corresponding member of ANAS G.I.Jalalov and expresses his gratitude to Doctor of technical science V.M.Fataliyev for their help and advice.

MAIN CONTENT OF THE DISSERTATION

The **introduction** of the dissertation, the relevance of the topic is substantiated, the purpose and tasks of the work, the methods of solving the issues, the main provisions defended, scientific innovations, the theoretical and practical significance of the work, approval and application, the structure and scope of the work are reflected.

The **first chapter** covers a review of the literature devoted to the modern scientific situation and ways of development of the methods of studying the phase transformations of gas-condensate systems, the conditions of the criteria of similarity during the study of these systems in the physical layer model, the methodology of conducting experiments based on these criteria, and provides the sequence of creating a new experimental facility on the basis of this.

Since the reservoir systems have a very complex composition, it is very difficult to study the phase relations of such systems under complex thermobaric conditions. In order to create perfect mathematical and thermodynamic models in such studies, the lithological composition of the formation reservoir, the amount of residual water in the formation, the group composition and component composition of the formation system, the amount of non-hydrocarbon components, thermobaric conditions and other factors should be taken into account. However, such diversity makes research so difficult that deterministic analyzes and model testing become impossible. In such cases, there is a greater need for experimental studies.

The joint study of reservoir systems in the gaskondnsat field requires the integration of separate scientific knowledge and scientific worldview. These studies are: 1) geometric dimensions, geological properties and lithological composition of the investigated reservoir; 2) reservoir properties, physical-mechanical and hydrodynamic properties of the layer; 3) physico-chemical properties of the reservoir system or liquid and gas, mutual solubility and phase relations; 4) allows determining the thermobaric conditions of the horizon. Physico-chemical, hydrodynamic and thermodynamic properties of the formation product or gas and liquid mixture are determined on the basis of laboratory studies. Despite the fact that these data are important in determining the operational methods of the field, their study in laboratory conditions is associated with a number of difficulties:

1. Difficulties and errors associated with the technology of obtaining samples taken from the reservoir, packing and weathering of the samples.
2. Since the taken sample characterizes only one point of the layer, it is necessary to test its degree of reliability and conduct additional research.
3. The degree of accuracy of laboratory devices and the possibility of influence of the elements used in these devices on the studied process.
4. Difficulties arising from the modeling of natural processes and errors caused by the created models.
5. Procedures used for conducting laboratory research and the difficulties and errors caused by these procedures.
6. Defects related to the interpretation of the data obtained as a result of laboratory analysis and the theoretical knowledge used for this.

The research works presented in the thesis work: depletion mode of gas condensate fields; injection of gases of different composition into the layer; cover complex issues such as re-production of hydrocarbon condensate deposited in the reservoir and processes such as displacement, expansion, condensation, dispersion, diffusion and evaporation under reservoir conditions. Therefore, the correct modeling of these factors and the precise determination of similarity criteria and conducting experiments under these conditions have been considered as a very important principle. The principles of geometric, thermodynamic, chemical and hydrodynamic similarity were used during the studies that considered this point. At the same time, satisfaction of the principles of similarity was taken into account in the selection of parameters and the determination of their change intervals, as well as in the determination of factors influencing the studied parameters.

Sometimes researchers model the layer system by replacing only one component to simplify their research. Such studies do not reflect real processes, although they allow for correct and easy determination of the sought parameters.

Based on our researches, it has been shown that it is more appropriate to study gas condensate systems as a mixture of dispersed medium - gas components and dispersed phase - liquid components.

The gas samples used in our experiments were taken from the wells belonging to the "Bulla-daniz", "Bahar", "Gunashli" fields and from the "Dashgil" gas primary processing station to gas cylinders with special sampling devices. Therefore, there was no need to recombine the gas components, the samples were analyzed in a gas chromatograph, and the component composition was changed or kept constant depending on the requirements of the experiments to be performed.

It is known that even an insignificant change in the composition of the hydrocarbon condensate in the gas condensate system causes a serious change in the phase transition processes. Natural hydrocarbon condensate was used during the experiments in the dissertation work. The component composition of the initial liquid was studied by means of liquid chromatography and kept constant depending on the purpose of the study, thereby eliminating unplanned side effects of its composition on the studied process.

In line with the conventional rules, recombination of the gas condensate system is carried out directly in the PVT bomb. PVT bombs of UGK-3 and УФР-2 types were used for this purpose in the dissertation work. The main goal here is to correctly determine the mass of liquid components in a unit gas volume of the system.

Typically, the depletion of the horizon is modeled by differential condensation of a gas condensate system in a laboratory equipment. However, a state of thermodynamic disequilibrium may arise here, which may cause sharp deviations from the processes taking place in the layer. Therefore, the rate of change of pressure (P) as a function of time (t) was taken as the main leading parameter.

Since the gas-condensate system is studied here as a dispersed system and the main researches are carried out in the layer model, other issues arising from this are: the change of the surface energy and the effect of surface forces; sorption phenomena; phenomena arising from dispersion and other colloidal properties; normal evaporation and condensation, filtration, etc. processes should also be taken into account. For this purpose, the influence of the rate of change of pressure in a given interval on the state of thermodynamic equilibrium was studied experimentally in the form of dependence (1).

$$K(P) = f(\frac{dP}{dt}) \tag{1}$$

Where: *K(P)* is the condensate factor of the gas removed from the system at a given pressure during differential condensation (for steady state).

It is known that the condensate factor of the gas produced during differential condensation may depend on the temperature-T, the condensate content - δ_k, the gas content - δ_q, the initial condensate factor - K_{ilk} and the properties of the environment - $\delta_{m\ddot{u}h}$. If we take them into account in expression (1) and consider the condensate factor in any pressure interval - ΔP, we eliminate the effect of pressure ($K_{\Delta P}$) and it can be written as follows:

$$K_{\Delta P} = f(\frac{dp}{dt}, T, \delta_q, \delta_k, K_{ilk}, \delta_{m\ddot{u}h}) \tag{2}$$

(2) dependence was studied in the vertical layer model created on the basis of similarity criteria and in the UKG-3 type PVT bomb. The obtained results revealed that the effect of temperature on the process, that is, on the condensate factor of the produced gas, does not exceed 2.24%. The effect of temperature was not taken into account as it was within the error range of these experiments. The system was differentially condensed from 30±0.5 MPa to 0.5 MPa (retrograde condensation pressure set at 25.3±0.3 MPa) in both environments (in the bomb and reservoir model). The obtained result can be written as expression (3).

$$K_{\Delta p} = \begin{cases} a\frac{dP}{dt} + b, & \frac{dP}{dt} > 1{,}667 \pm 0{,}04 \cdot 10^{-3} MPa/sec \\ K_{\Delta p}^{s}, & \frac{dP}{dt} \le 1{,}667 \pm 0{,}04 \cdot 10^{-3} MPa/sec \end{cases} \quad (3)$$

From this: coefficients of linear dependence a and b;

$K_{\Delta p}^{s}$- - is the stabilized value of the gas produced in the given pressure interval depending on $\frac{dP}{dt}$.

According to the expression (3), the difference between the reservoir model and the PVT bomb is $\pm 0{,}04 \times 10^{-4}$ MPa/sec, taking into account the capabilities of the device, the rate of pressure drop during the experiments was assumed to be less than $1{,}66 \times 10^{-3}$ MPa/sec.

Considering the approach of D.A.Efros, as a result of the conducted studies, the range of values of πk satisfying the condition of thermodynamic equilibrium for nature was determined to be $0{,}2 \times 10^{-18}$ - $0{,}12 \times 10^{-13}$. In the depletion process, gas and liquid velocities have been determined to be 1.5-27 m/h or 3.5-50 volumes of porous media per hour.

Thus, by analyzing all the mentioned factors, the technical capabilities of the used equipment were evaluated, and all similarity criteria were taken into account during the planning and conducting of experiments.

The second chapter is devoted to the problematic moments in the development of gas condensate deposits, the study of the characteristics of the phase relations of the layer systems, the detection of the factors influencing it, the study of its scientific essence, the investigation of solutions and the development of rational processing systems of the reservoirs.

Usually, the development of gas condensate fields, especially in fields with higher formation pressure and temperature due to their deeper location, is designed without the application of formation stimulation methods. The fact that methods of artificial conditions on the formation require large funds and complex surface equipment increases the advantage of exploitation of the given field in the natural mode. However, a number of complications arising during the operation of the field due to natural energy increase the unrecoverable part of the natural raw materials of great industrial importance (remaining in the layer) and sharply increase the cost of additional measures to be taken for its subsequent production.

The conducted studies show that one of the main factors that cause the liquid condensate to settle in the formation is the component composition of the gas condensate system. During the operation of gas condensate reservoirs in depletion mode, the heavy components that make up the reservoir system condense due to the drop in reservoir pressure. Precipitated hydrocarbon condensate forms as a thin film on the rock surface or as droplets in the pores. Condensate particles formed in this way remain motionless under the influence of adsorption and capillary forces and do not participate in hydrodynamic processes. Since the condensation process depends on the value of pressure, it accumulates more in the zones of the layer with low pressure and porosity. Over time, the saturation with condensate in such areas increases and the saturation of the porous medium reach a crisis point. Such a liquid band increases the resistance of the single-phase fluid to the bottom of the well and reduces its relative phase conductivity. As condensate saturation approaches the crisis state, this effect intensifies and significantly affects the productivity of the well. This factor becomes more acute in fields with low formation pressure and permeability, and can even cause the well to stop working.

Since the amount of produced fluid depends on the composition of the reservoir system and changes in thermodynamic parameters, physical-thermodynamic, physico-chemical and hydrodynamic processes in the field have a significant impact on the performance indicators. Therefore, the mentioned problems and their essence were studied in the porous layer model, by differential condensation of the gas condensate system in the pressure interval from 30 MPa (fully single-phase dispersed state of the system) to 6 MPa. The effect of porosity (m), temperature (t), condensate density (ρ) and residual water content (φ) on the percentage of extracted condensate (γ) at different pressure values was studied by means of rational planning. To study the influence of each parameter, five of their values were selected and studied in the form of $\gamma = f(t, m, \rho, \varphi)$. Through a sequential approach, it was possible to clarify the influence of all parameters separately, and the following dependence was obtained:

$$\gamma = -\frac{7{,}9}{19{,}124m - 2{,}627} - 0{,}28(0{,}1\varphi + 1)^2 - 0{,}181\rho + 0{,}3t + 143{,}84 \quad (4)$$

Numerous experimental studies conducted and the analysis of their results has been summarized and complications arising during the operation of gas condensate deposits in the depletion mode have been classified.

1. *Complications caused by a decrease in formation pressure.* During the operation of the reservoir in depletion mode, due to the decrease in formation pressure, the distance between molecules increases, the mass of the system decreases, and this leads to a decrease in the internal energy of the formation system. Although the volume of the formation system remains relatively stable, the field is generally exploited due to its expansion. Here, the process can be accepted as isothermal, since the layer temperature is continuously restored even if the temperature changes. Within this condition, the pressure dependence of the condensate factor of the layer system *K=f(P)* was investigated theoretically and experimentally. Let's assume that the condensate reserve of the taken gas condensate field is -V_k and the gas reserve is - V_q. In reservoir conditions (reservoir pressure (*P)* and temperature (*T)*), the volume of condensate dispersed in a unit volume of gas – K can be expressed as follows:

$$K = \frac{V_k(P)}{V_q(P)}, \; T = const \quad (5)$$

From here, K can be estimated (in units of m^3/m^3) by determining the volume of condensate and gas in the formation as a function of pressure at a constant value of the formation temperature. However, it is known that after the retrograde condensation pressure, part of the condensate starts to separate from the gas, so the character of expression (5) changes. According to this dependence, if K ≥ 1 at a given formation temperature, then all the gas is dissolved in the condensate, and the formation system can be considered as a single-phase liquid state with low density. Therefore, when $K=1$, i.e., at a given pressure and temperature, the mixture is on the verge of transition to a two-phase state, provided that the total volume of the gas components is equal to the volume of the liquid components. However, according to the thermodynamic studies of gas condensate systems, the layer system can maintain its single-phase state even in this case. At this time, the layer system changes from the "gas in liquid" colloid state to the "liquid gas" colloid state. Studies show that when the volume of a system increases isothermally, its compressibility weakens and the pressure reaches a value where the mixture behaves like a liquid. This pressure can be called the dispersion pressure of the system (P_{dhd}) or transition pressure. As it approaches that pressure, the volume of liquid fractions per unit volume of gas components approaches unity.

On the other hand, the fact that $V_q > V_k$ does not mean that the liquid is separated from the dispersed medium and simply indicates the transition of the liquid components from the role of the dispersed medium to the dispersed phase. According to expression (5), this transition state can be expressed as follows:

$$\left.\begin{aligned} K &= \frac{V_k(P)}{V_q(P)} \geq 1, \text{əgər } P \geq P_{dhd}, T = const \\ K &= \frac{V_k(P)}{V_q(P)} \leq 1, \text{əgər } P_{rk} \leq P \leq P_{dhd}, T = const \end{aligned}\right\} \tag{6}$$

As can be seen from expression (6), despite the change in the dispersed state of the system, it still remains in a single-phase state, but one of the conditions $P \geq P_{dhd}$ or $P_{rk} \leq P \leq P_{dhd}$ must be satisfied for this. When the pressure decreases from the P_{dhd} point, the pressure must drop below the retrograde condensation pressure (P_{rk}) for the system to become two-phase. This can be expressed mathematically as (7):

$$K = \frac{V_k(P)}{V_q(P)} < 1, \text{əgər } P \leq P_{rk}, T = const \tag{7}$$

Summarizing the conducted studies, for the cases $K>1$, $K=1$ and $K<1$, transition points of the layer system were found depending on the pressure, gas in liquid ($P \geq P_{dhd}$), liquid gas ($P_{rk} \leq P \leq P_{dhd}$) and two-phase - condensate and gas ($P \leq P_{rk} \leq P_{dhd}$) transition conditions are defined. Through experimental tests, the diagram of the phase state change during formation pressure reduction was constructed based on the data of several wells on the "Bulla-deniz" field, and the importance of its consideration during operation was shown.

$P \leq P_{rk}$ of the pressure, that is, the condensate factor of the gas phase begins to decrease rapidly depending on the pressure. At this time, since the temperature is fixed and other parameters depend only on the pressure, $K=f(P)$ was solved as a simple differential equation, and the proportionality coefficient between the α_p-condensate factor and the pressure was included and its importance was evaluated according to its physical essence. It was found that this parameter depends on pressure, composition and thermobaric conditions and has a unique value for each deposit. To investigate this, special experiments were conducted in different environments. Based on the dependence $\alpha_p = f(P)$, the retrograde and maximum condensation points (pressures) of the gas-condensate mixture were determined:

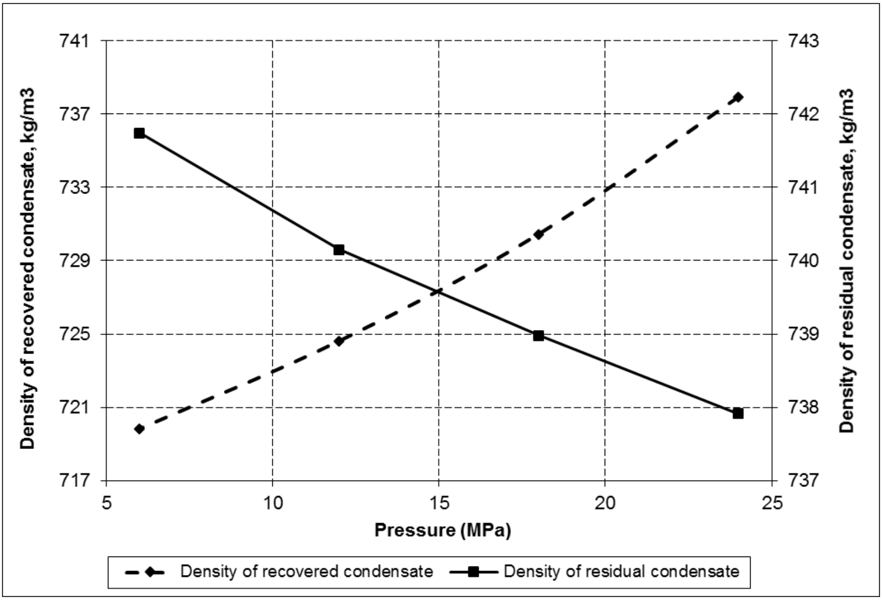
$$K = K_{ilk}(P_{ilk}, T_{lay}) e^{\alpha_p (P - P_{rk})} \tag{8}$$

In addition, the coefficient α_p also characterizes the stability of the dispersed state of the layer system. Thus, by controlling this coefficient, it is possible to regulate the stability of condensate in a dispersed environment and achieve more condensate production.

2. *Complications caused by a decrease in the density of the dispersed medium and phase and an increase in the density of the precipitated condensate.* Since the operation of gas condensate deposits in depletion mode occurs directly due to the decrease in reservoir pressure, a number of parameters that determine the hydrocarbon condensate that forms the dispersed phase with the

decrease in pressure remain in the dispersed environment: the internal energy of the system, the density of the condensate, the density of the gas environment, the condensate factor of the system, the process of gas dissolution in the condensate, etc. parameters also change. This change fundamentally affects the condensate yield of the field in addition to retrograde condensation. Therefore, the investigation of these factors can play an important role in determining ways to increase the productivity of the field.

The decrease of the pressure after the maximum condensation pressure causes the density of the outgoing condensate to stabilize and even relatively increase. In contrast, the density of the remaining condensate in the layer model increases almost linearly during the differential condensation process (graph 1).



Graph 1. Variation of the density of the condensate recovered during differential condensation in the reservoir model and remaining in the reservoir model

However, the intensity of this increase continues even at pressure values smaller than the maximum condensation pressure.

This is obviously due to the evaporation and production of relatively light components.

Taking this into account, the influence of the density of stable condensate in the primary layer system on the final condensate yield in gas condensate fields operated in depletion mode was also investigated. According to the obtained results, initially stable during exhaustion the density of the condensate strongly affects the final condensate yield. Thus, an increase in the density of the initial condensate in the layer from 700 kg/m^3 to 800 kg/m^3 reduces the final condensate yield to 18.1%, and this dependence is linear.

3. *Complications due to deterioration of gas-liquid ratios and interphase mutual solubility.* During differential condensation, the regularity of changes in the volume of gas dissolved in the retrograde condensate deposited in the PVT bomb and its pressure dependence on the amount of condensate of the gas phase, the volume of condensate removed depending on the pressure plane, and the current and final condensate yield of the field were investigated, along with the increase in its amount, the amount of dissolved gas in its unit volume decreases. This means that the separation of the condensate from the dispersed medium is accelerated and the surface tension at the gas-condensate boundary increases. Based on this, it was determined that one of the main principles is to increase or control the solubility coefficient of gas in retrograde condensate in order to increase the condensate yield during the operation of gas condensate fields in depletion mode.

On the other hand, it was found that during differential condensation, the density of the condensate in the gas condensate system remaining in the "layer" increases due to the increase in the concentration of relatively heavy components in its composition. In this case, the condensation pressure of the system also increases. At the same time, the increase in the density of the deposited condensate worsens the mutual solubility between the gas and liquid components that make up the formation system. It is the role of these two factors that increases the importance of considering these factors in the development of the methodology of influence methods.

Specifically, during the exhaustion of the VII horizon of the "Bulla-deniz" field, during the time when the condensation pressure of the extracted layer system dropped from 71 MPa to 11 MPa, a decrease in the condensate factor of the gas phase from 361 g/m^3 to 79 g/m^3 was observed. According to the calculations based on the principle of mass balance, the condensate factor of the general system remaining in the formation has increased up to 3 times due to the increase in the amount of condensate deposited in the formation along the mentioned horizon.

This means that if the injected working agent is designed for retrograde evaporation of the condensate deposited in the formation or re-dispersion in the gas medium, then high efficiency cannot be expected by applying classical methods.

4. *Complications arising from the irregular change of liquid and gas fractions.* Usually, the gas condensate factor refers to the volume of condensate dispersed in the gas, but it is known that the hydrocarbon condensate present in the field can be divided into two types according to its physical and thermodynamic conditions. Condensate mass that disperses in the gas phase and forms the dispersed phase ($V_{k.d}$) and is in close contact with the rock surface or could not be dispersed due to the heavy components in it and settled on the rock surface ($V_{k.q}$). Then, the condensate per unit volume of gas in the bed (K^*) can be expressed as follows.

$$K^* = \frac{V_{k \cdot d} + V_{k \cdot q}}{V_q} \qquad (9)$$

It is known that, according to traditionally accepted conditions, this liquid mass does not participate in hydrodynamic and thermodynamic processes if the amount of residual condensate does not exceed the values of the formation pressure ((P_{lay}) greater than the retrograde condensation pressure (P_{rk}) in the initial state of the formation. Therefore, its change is not taken into account during the processing of deposits. Nevertheless, research conducted on the "Bulla Sea" field has proven that this type of condensate is involved in the filtration process from the initial moment of the field and a certain amount is extracted through wells. If the pressure of the given layer decreases to any value $P_{lay \cdot i}$, then the condensate factor of the layer can be written:

$$K_i^* = \begin{cases} \frac{(V_{k \cdot d} - \sum V_{k \cdot d \cdot ç}) + (V_{k \cdot q} - \sum V_{k \cdot q \cdot ç})}{V_q - \sum V_{q \cdot ç}}, & P_{lay \cdot i} \geq P_{rk}, \quad i = 1, 2, \dots n \\ \frac{(V_{k \cdot d} - \sum V_{k \cdot d \cdot ç}) + (V_{k \cdot q} - \sum V_{k \cdot q \cdot ç}) + (\sum V_{k \cdot r} - \sum V_{k \cdot r \cdot ç})}{V_q - \sum V_{q \cdot ç}}, & P_{lay \cdot i} < P_{rk}, \quad i = 1, 2, \dots n \end{cases} \quad (10)$$

Where: $\sum V_{k \cdot d \cdot ç}$, $\sum V_{k \cdot q \cdot ç}$ and $\sum V_{q \cdot ç}$ - is the total volume of dispersed condensate, residual condensate and gas produced up to any stage i, respectively (brought to standard conditions);

$\sum V_{k \cdot r}$, $\sum V_{k \cdot r \cdot ç}$ - are the total volumes of retrograde precipitated condensate and the part removed from that condensate at i stage (brought to standard conditions).

During the operation of gas condensate fields, the reservoir system changes in a complex way, depending on the composition of the mixture produced from the reservoir, either at higher or lower values of the reservoir pressure than the retrograde condensation pressure. These changes are observed with transition points that can dramatically affect the operational performance of the field. This means that the phase diagram of the formation system is subject to regular changes and it depends on the condensate factor of the formation, the amount of residual condensate, and the fractional composition of the system. Irregular changes in the fractional composition of the formation system during depletion have a negative effect on the stability of the dispersed phase and the dispersing ability of the dispersed medium, increasing retrograde losses.

5. *Complications caused by the influence of the porous environment.* As mentioned, retrograde condensation occurs at higher pressures under bed conditions. Thus, when the reservoir system is at a higher pressure than the retrograde condensation (set in the PVT bomb), the condensations caused by the effect of gravitational forces on the heavy dispersed particles differ from each other when the pressure of the rock surface and formation is smaller than the retrograde condensation pressure.

It is known that due to the pressure drop during exhaustion, the compensator (F_m) of the forces acting on the molecules saturating the surface of the aerosol increases due to the decrease in the density of the dispersed medium, and the molecules on the surface are directed towards the center of the aerosol. This means that the aerosol density and surface tension - $\sigma_{q \cdot k}$ (at the gas-condensate boundary) increases with the decrease in layer pressure. In this case, during exhaustion, the condition of dispersed particle settling and combining with other particles of the same composition is improved. When such an aerosol comes into contact with the rock surface, the surface relations change in a more complex way. If we replace the surface energy not touching the rock surface - $E_{q.k}$, the surface energy difference in the contact area after contact with the rock surface - $\Delta E_{s.k}$, the surface tension on the surface in contact with the rock - $\sigma_{s.k}$and the area of the contact surface with the rock by the area of the segment of the sphere , then we can write the final surface energy (E) as:

$$E = E_{q.k} - \Delta E_{s.k} = 4\pi r^2 \sigma_{q.k} - 2\pi r h(\sigma_{q.k} - \sigma_{s.k})$$

From here,

$$E = 2\pi r(2r\sigma_{q.k} - h(\sigma_{q.k} - \sigma_{s.k})) \tag{11}$$

From the theoretical expression obtained for these relations, it is known that in the area of contact of the condensate particle with the rock surface, its surface energy increases and the surface tension decreases. Here, the final surface energy depends on the difference between the surface tensions of the aerosol and the rock and gas medium and the height (h) of the segment of the aerosol meeting the rock surface. Depending on the aerosol form, parameter h characterizes the ability of rock to be wetted by condensate. Its approach to zero means that the tangential area approaches zero, which means that the rock is hydrophilic, while increasing h means that the rock is hydrophilic. Here, the concentration of phases on the touching surfaces is observed by the adsorption process, despite the increase in surface energy, it does not help the dispersion of the condensate, but causes its early condensation on the surface.

From the analysis of numerous experiments, it was found that the porosity of the medium affects the differential condensation process only up to a certain value (here in the range of 25-30%). From this value, the increase in porosity does not significantly affect the amount of condensate produced, and the process approaches that of an empty vessel. It was found that the effect of the specific surface of the rock has a similar character at different temperatures and varies in different intervals of porosity. For example: when the porosity is ≥30 % the amount of produced condensate is reduced by only 6.5%, when it is <30%, the condensate produced as a result of differential condensation is reduced to 20%. Another conclusion is obtained from this that if the specific surface of the rock is smaller than 150000m^2/m^3, it does not have a noticeable effect on the differential condensation process. Thus, in conclusion, it can be noted that the large specific surface of the rock leads to large contact areas, and on the other hand, the hydrophilicity of the rock (quartz, gypsum, etc.) accelerates the adsorption process and increases the negative effect on the depletion process. It was found out from the conducted studies that as the degree of heterogeneity of the layer increases, the radius of the condensate ring formed in the well bottom zone, the degree of saturation of the rock with condensate, and the rate of liquid deposition increase. This factor also reduces the duration of effect of the method of impacting the layer.

In order to compare with real bed conditions, calculations were made on the example of the "Bulla-deniz" bed. According to the calculation, the formation condensate yield will be 32.96% at the formation pressure value of 6 MPa. In PVT bomb, this value is 40.76%. These results show that the collection properties of the porous medium have a significant effect on the depletion process of the gas condensate field and the importance of considering this factor in projects.

6. *Effect of reservoir temperature on depletion process and results.* Since gas condensate systems are dispersed systems, operational expectations are higher in fields with high formation temperature. This result is also evident from the expressions of the

enthalpy change of the layer system during exhaustion (for isochoric and isobaric processes). In both cases, increasing the temperature increases the internal energy. If we do not take into account the temperature expansion of the layer model in our experiments, we can assume that the process is isochoric. At this time, the additional heat supplied to the system is not used for the work done against external forces, but for the internal energy of the system and technical work. This increases the stability of the dispersed state of the layer system. If we consider the temperature increase as an isobaric process, then the density of the dispersed layer system decreases as the potential energy of the pressure is generated due to the expansion of the volume, that is, when the distance between the particles increases, the internal potential energy, which is very important for the stability of the aerosol, decreases. It is clear that increasing the temperature of dispersed systems leads to the separation and fragmentation of the dispersed phase, and in this case, increasing the temperature in an isochoric process increases the stability of the system more.

The increase in temperature during depletion reduces the surface tension at the interface of the condensate-gas-rock phases. This slows down the separation of the dispersed phase or retrograde condensation in porous media. According to experimental studies, a 1.5-fold increase in temperature reduces the difference between the final condensate yield obtained in a PVT bomb with a layer model by more than 2 times. In systems consisting of heavy fractions, this result is higher. Thus, with an increase in temperature from 80 °C to 110 °C, it is possible to recover 9% of the lost condensate due to an increase in the condensate density from 700 kg/m^3 to 800 kg/m^3. This is due to the increase of the internal kinetic energy of the system due to the effect of temperature, the improvement of the ability of individual components to evaporate, the reduction of the retrograde condensation pressure of the system, the improvement of the conditions for the dispersion of liquid components, and the deterioration of the sorption processes associated with the rock surface. However, high temperature increases the density of retrograde condensate at the last stage of operation, making it difficult to re-produce it, which is one of the important issues to consider in field operation.

7. *The impact of formation water on the depletion process and its consequences.* Various experiments were conducted in order to study the effect of formation water on the depletion process. According to the obtained results, the increase of water saturation in the formation model to 40% is determined to reduce the amount of total condensate produced to 32% depending on the values of condensate density, porosity and temperature. It is known that the increase of formation water mainly causes the increase of liquid-gas ratio of the formation system. In our experiments, increasing the water saturation of the formation model from 0 to 40% increased the total volume of liquid per unit volume of the gas phase from 150 g/m^3 to 2937 g/m^3. Of course, this is a rather large number for the negative impact on the stability of dispersed systems, and the elimination of this complication should be taken into account when injecting water into the deposits. According to those studies, the role of the porous medium during the effect of residual water on the phase transformation of the gas condensate system is not significant. Thus, when the porosity increases from 0.1912 to 0.4012 in a waterless environment, the condensate production increases by 17%, while this figure is 22% when the porosity is saturated with 40% water. It turns out that the production of water by evaporation during differential condensation compensates the condensate losses to a certain extent.

Based on theoretical considerations and certain experimental data, gas separation from retrograde deposited condensate and free residual water occurs with isothermal pressure reduction. At this time, since the amount of gas released from the condensate is large, the surface tension at the condensate-gas boundary increases more than the surface tension between water and gas. This means that as the pressure decreases, the surface tension at the condensate-water contact plane also decreases. Under certain thermobaric conditions (high formation temperature, etc.), "condensate in water" can even cause the formation of emulsions. This can make it more difficult to remove the settled condensate at later stages and should be taken into account when operating fields with high residual water in depletion and water injection modes.

In the third chapter, the general principles, difficulties and ways of overcoming these difficulties have been investigated in gas condensate fields, keeping the pressure of the layer system at a pressure higher than or equal to the retrograde condensation pressure. A number of practical, experimental and mathematical simulation data known from the literature were analyzed, the modern characteristics of the existing problems were investigated, and the direction of research was determined based on the obtained data. Since these studies are based on experimental experiments, the problems of creating and justifying the experimental procedure of the process have also been eliminated.

The most ideal method, which theoretically enables the complete production of condensate and gas reserves of the gas condensate field, is the gas cycling method. If we analyze the data of the fields processed by this method together with the results of other research studies, a number of signs of gas injection into the layer in this way can be specifically noted: 1) maintenance of the single-phase or initial thermodynamic state of the gas condensate system; 2) movement or vaporization of the hydrocarbon fluid in the formation in the initial state of the formation; 3) permanent reduction of the condensate factor of the formation system and, accordingly, improvement of phase permeability due to gas; 4) high economic costs at the initial moment of operation; 5) increase in the number of gas injection wells, depending on the geological condition of the field and the characteristics of the reservoir; 6) complexity and cost of ground equipment. These factors are the main characteristics of formation gas injection, and these factors are also taken into account when creating a thermodynamic model of gas injection.

Experiments carried out in this area show that by circulating the injected gas in the formation, the deposited condensate can be completely vaporized. However, according to subsequent studies, it was determined that the formation pressure has such a value that it is impossible to completely dissolve the condensate that settles to this limit, regardless of the cycles of circulation with dry gas, and the condensate remains in the bed. Here, the importance of studying the amount and composition of heavy components in the formation system, new working agents, new mixtures formed during their injection into the formation, and the physico-chemical and thermodynamic properties of these mixtures emerges. Taking this into account, the change of phase ratios occurring in the formation during the injection of the released gas back into the formation was considered.

Theoretically, it has been shown that the gas condensate field gradually turns into a gas field during gas cycling operation. However, based on the obtained results, it can be said that the following advantages can be achieved by partially maintaining the formation pressure:

1) Part of the costs can be reduced and profits can be increased by giving a part of the produced gas to the users.

2) Reducing the gas injected into the formation increases the reliability of the gas injection systems and ensures uninterrupted operation.

3) Since the decrease in formation pressure leads to a decrease in the working pressure and gas injection pressure of the technological facilities, it is possible to achieve safe operation of surface equipment and reduction of current and capital maintenance costs.

4) It is possible to completely stop the gas injection process at a certain moment of the operation of the field and continue the operation in the gas mode.

In contrast to other researchers, gas injection into the formation with partial maintenance of the formation pressure was studied in more detail through experimental studies and the principles of selection of the working agent were determined.

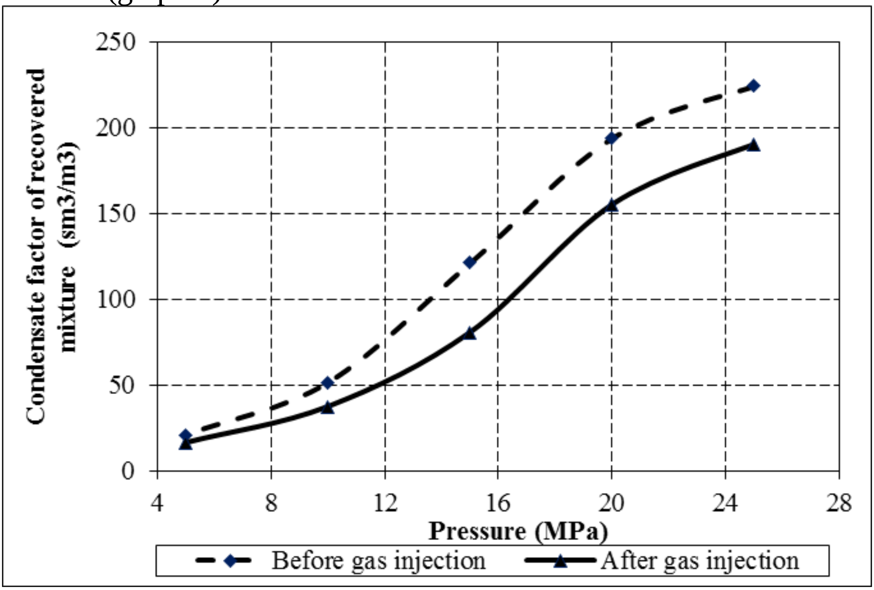
The experiments were carried out in a standard PVT bomb. A gas condensate system with a condensate factor of 200 g/m3 is created in a PVT bomb using a dry natural gas cylinder, a hydrocarbon condensate container and special hydraulic presses. During all the experiments, the initial hydrocarbon system was created at room temperature and under a pressure of 0.6 MPa, but the studies were usually carried out at a temperature of 95 °C. Since the same system was used during the experiments, the condensation pressure was set at the same 28 MPa, and the initial pressure of the system was taken as 30 MPa. Thus, the pressure is reduced from 30 MPa to 25 MPa according to the first stage of differential condensation. According to the general thermodynamic rules, samples are taken from the separation and degassing gases and their physical and chemical properties are determined. The amount of extracted condensate and its physical properties are studied. After that, the pressure of the system is raised to 30MPa by injecting compressed natural dry gas through a special press, under the condition that the equilibrium of the condensate and gas phases is expected in the PVT bomb. At this time, the volume and temperature of the system are kept constant. Thermodynamic equilibrium is again achieved and differential condensation is carried out in the same way as before to 25 MPa. This time, the relevant data is obtained, and the first experiment is considered to be over.

The next experiments were carried out in the same manner as described above, but for other levels of pressure. For example, in the second experiment (for the pressure step of 25-20 MPa), the pressure is first changed from 30 MPa to 25 MPa and then to 20 MPa according to the mentioned method, it is raised to 25 MPa by injecting gas, and differential condensation is done again to 20 MPa.

Thus, according to different levels of pressure, five experiments were carried out by reducing the pressure to 5MPa. Since these data obtained for different stages of pressure include two different differential condensation processes - "before gas injection" and "after gas injection", it allowed to study the normal depletion mode of the system, the depletion mode with gas injection and the effectiveness of gas injection at different stages of depletion.

The analysis of the results of the experiments showed that the results obtained in both cases are consistent with the classical rules that determine the differential condensation process, that is, the amount of extracted gas increases according to the decrease in pressure, while the extracted condensate and its density decrease. At the same time, as the amount of condensate deposited in the bomb increases, the amount of condensate removed by the pressure stages decreases in percentage compared to the initial-total condensate reserve.

At any value of the pressure, the condensate factor of the mixture removed before gas injection is greater than the value obtained after gas injection. Although this difference is large in the upper values of the pressure, it decreases with the decrease of the pressure and becomes almost equal in the last step of the pressure. Here, too, the condensate per unit gas volume of the system remaining in the PVT bomb before gas injection is greater than that after gas injection, and as the pressure decreases, this difference can be seen to decrease (graph 2).



Graph 2. Variation of the condensate factor of the recovered mixture before and after degassing depending on the pressure

The reasons for this seemingly contradictory result were also investigated. It is known that the initial condensate factor is

267.83cm^3/m^3. In the first step, the pressure is reduced from 30 MPa to 25 MPa. At this time, the condensate factor of the obtained mixture decreases to 224.36 cm^3/m^3. It is clear that this is due to the beginning of excess condensation, that is, since the retrograde condensation pressure of the system is 28 MPa, there is already condensate deposited in the PVT, and due to this, the condensate factor of the resulting mixture decreases, and vice versa, the amount of condensate per unit gas volume of the system remaining in the PVT (in general, gas and taking into account the total amount of condensate in the liquid phase) increases.

Therefore, at 25 MPa, there are already liquid and gas phases in the system, and the density of the precipitated condensate is relatively large, since heavier components initially condense. After that, gas is injected into the PVT bomb and the pressure is raised to 30 MPa. Since additional gas is injected into the system, the amount of condensate per unit gas volume of the system in the bomb decreases from 274.34 cm^3/m^3 to 238.68 cm^3/m^3. The retrograde condensation pressure of such a system is set at 26.8 MPa, which is 1.2 MPa less than the original system.

Despite the reduction of the condensate factor of the mixture extracted at 25 MPa after the system is differentially condensed again (because the condensate factor of the system differentially condensed for the second time was smaller than before), the amount of condensate per unit gas volume of the system remaining at PVT is also reduced. Thus, these events are repeated at all pressure levels. However, at lower pressure levels, the pre- and post-injection results are closer to each other, since vaporization by gas injection is relatively weak at low pressure values.

Apparently, the condensate removed after gas injection

density is always greater, but this difference between densities decreases as the pressure decreases. This is due to the ability of the gas injected at higher pressures to vaporize the hydrocarbon condensate better. Thus, based on the results obtained, the following conclusions can be noted:

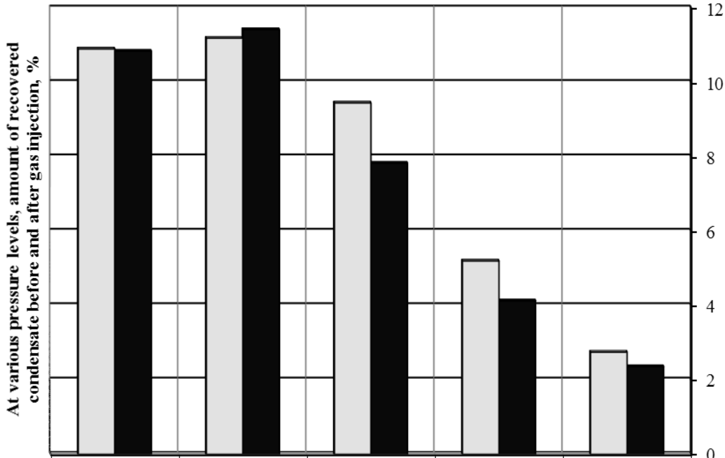
1. During the injection of dry natural gas into the formation,

the amount of light gas components that make up the formation system increases, the condensate factor of the field or the volume of condensate per unit volume of gas decreases, and as a result, the dispersion of hydrocarbon liquid improves. Thus, the retrograde condensation pressure of the formation system is reduced. Therefore, by keeping the formation system in a single-phase state, it is possible to operate the field in partial depletion mode;

2. When designing the operation of gas condensate deposits in the mode of partial maintenance of formation pressure, the composition of the formation system, the ratio of liquid and gas phases, the ability of the working agent to disperse the precipitated condensate, and the change in retrograde condensation pressure should be taken into account. At the same time, methods of managing these factors should be determined.

Experimental studies have shown that if formation gas injection begins at pressures below the retrograde condensation pressure of the formation system, the injected working agent must be capable of dispersing the precipitated heavy components when mixed with the formation system. In addition, vaporization of precipitated condensate by gas injection is more efficient at higher formation pressure values. In order to confirm this again, the ratio of the condensate extracted at different pressure stages to the volume of stable condensate in the PVT bomb before starting differential condensation at each stage was studied. During differential condensation, both before and after gas injection, the condensate yield at the upper stages of pressure – the ratio of the extracted condensate to the initial condensate reserve in the pressure interval is greater, and its decrease is observed with the decrease in pressure (graph 3).

This phenomenon is characteristic of the depletion mode. However, a slightly different trend is observed in the results, i.e., the amount of condensate removed in a given pressure interval, as a percentage of the volume of stable condensate in the PVT before differential condensation in that interval, in the second stage of pressure, i.e., the amount of percentage compared to the volume (25-

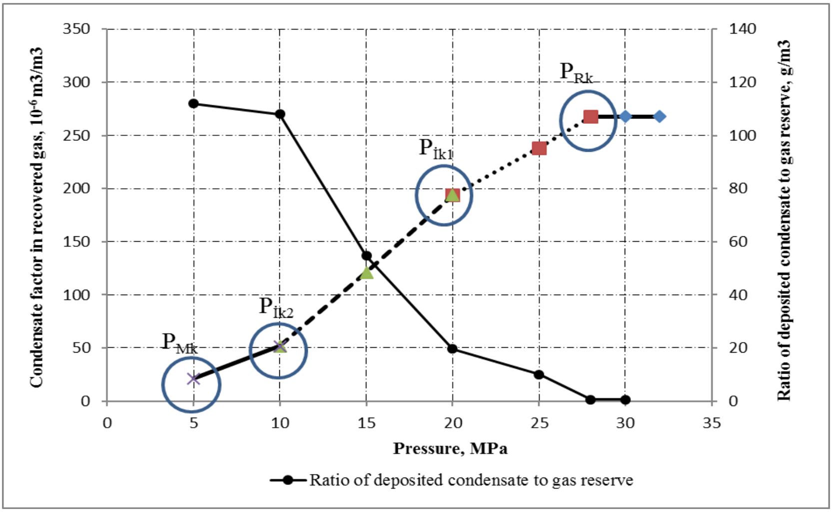


	1	2	3	4	5
Before gas injection	*10.9*	*11.19*	*9.45*	*5.2*	*2.75*
After gas injection	*10.84*	*11.42*	*7.83*	*4.13*	*2.36*

Graph 3. Amount of condensate recovered in percentage after and before gas injection at different levels of pressure. Here: 1 (30-25 MPa); 2 (25-20 MPa); 3 (20-15 MPa); 4 (15-10 MPa) and 5 (10-5 MPa) are pressure intervals

20 MPa) in the second stage of pressure, that is, an increase in the range of (25-20 MPa) is observed. This increase is observed both before and after gas injection. Although the condensing pressure of the studied primary system is 28 MPa, condensate deposition during differential condensation is mainly intensified at pressures below 20 MPa. At the same time, it can be seen from the received data that the main mass of extracted condensate coincides with the pressure interval of 30-20 MPa. For these reasons, the efficiency of gas injection is higher in the mentioned interval of pressure.

In general, the pressure dependence of the condensate factor of the gas produced in a separate pressure stage during differential condensation can be expressed graphically at different operating stages of the field. Based on the conducted experimental studies, it can be shown graphically as in graph 4.



Graph 4. The regularity of changes of liquid and gas phases during differential condensation of the gas condensate system (P_{Rk}-retrograde condensation, $P_{İk1}$-intensification of condensation, $P_{İk2}$-intensive condensation are values of final and P_{Mk}-maximum condensation pressures)

Here, in addition to the condensate factor of the released gas, the change in the ratio of the condensate remaining in the formation to the total gas reserve is also given. As can be seen from both dependences, the change depending on the pressure can be shown in the form of straight lines of different character. Therefore, since the initial or initial pressure - P_{ilk} (30 MPa in this case) is greater than the retrograde condensation pressure, the pressure components $|P_{ilk}\ P_{Rk}|$, $|P_{Rk}\ P_{İk1}|$, $|P_{İk1}\ P_{İk2}|$, and $|P_{İk2}\ P_{Mk}|$ can be written as

$|P_{ilk}\ P_{Rk}|$ - the condensate factor of the extracted gas remains constant. Since the separation of liquid from gas does not occur during differential condensation, despite the decrease in the volume of liquid and gas per unit volume of the system, the gas condensate factor remains constant. For this reason, maximum gas and condensate production can be achieved by influencing the reservoir in this range of pressure and keeping the "reservoir" pressure in this range.

$|P_{Rk}\ P_{İk1}|$ - retrograde condensation begins in the fragment and precipitation of relatively heavy components occurs. The total amount of condensate produced in this interval was 20.87% according to the total condensate reserve, and after gas injection, it was 22.26%. The condensate factor of the exhaust gas rises to 208.681 cm^3/m^3, and the condensate factor of the remaining system rises to 281.9 cm^3/m^3, and after gas injection, these parameters decrease to 170.62 cm^3/m^3 and 250.51 cm^3/m^3, respectively. These figures show that the pressure, temperature and composition of the "bed system" in this pressure range further improve the dispersing ability of the gas phase. This is due to the fact that the gas phase, that is, the dispersed medium, is richer in heavy components. As can be seen from the results, the maximum gas and condensate yield can be achieved by keeping the reservoir pressure in this range.

$|P_{İk1}\ P_{İk2}|$ - the total amount of the condensate produced in the section is 11.22%, and after degassing, it is 11.96% compared to the total reserve. The condensate factor of the outgoing gas is 86.46cm^3/m^3, and the condensate factor of the remaining system is 402.95 cm^3/m^3. This means a double deterioration compared to the previous pressure interval. After drilling, the values of these parameters are 59.1 cm^3/m^3 and 379.52 cm^3/m^3, respectively. This means that the pressure required for complete dispersion of the system remaining in the "layer" is higher than 45 MPa. Since gas reinjection reduces the moisture content of the gas phase, dissolution of the precipitated liquid is less efficient. For this reason, even maintaining the pressure in this interval results in certain condensate losses.

$|P_{İk2}\ P_{Mk}|$ - the amount of condensate produced in the piece is 1.87% before gas injection, and 2.32 % after gas injection. At this time, the condensate factor of the system remaining in the bomb is 1146.05 cm^3/m^3, which is not a favorable thermobaric condition for vaporization of the precipitated condensate. Since the gas injection evaporates only the light components, the density of the resulting condensate decreases sharply (686.2 kg/m^3), while the density of the remaining condensate increases (736 kg/m^3). This shows that the process is not efficient.

On the basis of the experiments, it is concluded that the effect of the gas mixture on the layer system with retrograde condensation in the pressure interval "beginning of intensive condensation" - $|P_{Rk}$ $P_{\dot{I}k1}|$ starting is more efficient. At the same time, these data prove that with the beginning of gas injection into the reservoir at the indicated interval, it is possible to achieve the same efficiency as the results of the full reservoir pressure or full gas cycling process.

In addition to all this, other important characteristics of the working agent should be taken into account during the partial maintenance of formation pressure. Based on the research conducted by us, it was determined that two factors are important here:

1) the working agent injected into the formation must have a good solubility in the hydrocarbon condensate to ensure the evaporation of the precipitated condensate or seepage towards the production well, in addition to controlling the formation pressure drop rate;

2) the working agent must have a high internal energy, since the depletion of layer energy is also assumed during the injection of the working agent. This should ensure the re-dispersion of the precipitated condensate, as well as the stability of the liquid components that make up the dispersed phase in the gas environment.

According to the conducted research, it was determined that if the gas condensate system contains gas components that are better soluble in the condensate and can disperse it better (CH_4 and CO_2 in the indicated case), then the dispersed phase maintains its stability up to lower pressures and more condensate is produced during differential condensation. Production conditions are created. Therefore, it is possible to control the dispersed state of the formation system by controlling the composition of the working agent during the partial maintenance of formation pressure.

The fourth chapter introduces the treatment of the well-bottom zone in gas condensate fields with gases of different composition was investigated through theoretical and experimental studies and ways of increasing its efficiency.

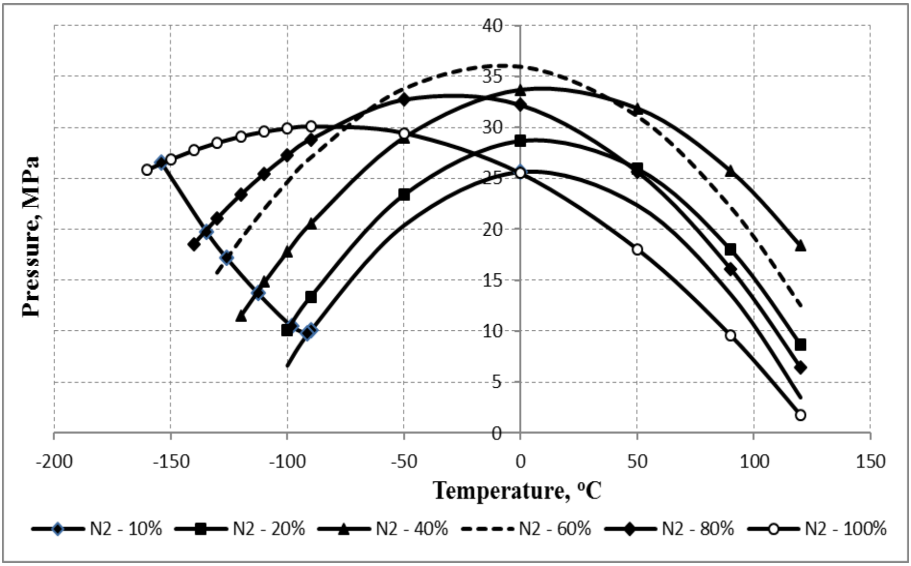
The conducted studies have shown that it is possible to vaporize the condensate deposited in the layer with gases of different composition. For this purpose, the mechanism of condensate dispersion, factors affecting it, working agents with different compositions and ways of increasing their efficiency were studied. Since the researched issues have a physical-thermodynamic fundamental nature, the researches were carried out in a PVT bomb isolated from external factors.

First of all, the effect of nitrogen gas as a working agent was studied in order to remove the condensate settled in the layer. Nitrogen gas is one of the working agents used in the development of gas condensate fields or for vaporization of retrograde deposited condensate at the last stage of operation or tested as a research object. Through experiments, we have studied a wider range of nitrogen gas concentration in the natural system, and by analyzing these data, we have explored relatively effective options for the application of this working agent.

Samples of well No. 46 of the "Bulla-deniz" gas condensate field were used to create the system. The created gas condensate system was studied according to the contact condensation procedure at a temperature of 100 °C. For the natural system, the retrograde condensation pressure is 22.8 MPa, and the maximum condensation pressure is set in the range of 12-14 MPa. Evaporation of precipitated condensate was carried out at a pressure of 12 MPa, approximately at the lower limit of maximum condensation. In the case of thermodynamic equilibrium, the gas phase was gradually removed at that pressure and temperature. The gas phase was removed and the natural gas mixture containing 10, 20, 40, 60, 80% nitrogen was replaced with 100% nitrogen gas, the contact condensation process was repeated according to the new system, and the contact isotherm and retrograde condensation pressure were determined. After that, the amount of gas dissolved in a unit volume of the condensate phase and the amount of condensate dispersed in a unit volume of the gas phase was determined. After removing the gas phase of the system at a temperature of 100 °C and a pressure of 12 MPa, that gas mixture (freed from the dispersed condensate) was returned to the system again. According to this rule, 4 contact cycles of the given working agent with the precipitated condensate were carried out. From the obtained results, it is known that as the amount of nitrogen in the gas mixture increases, the amount of dispersed condensate and the amount of gas dissolved in the precipitated condensate decreases. When the content of nitrogen in the gas phase of the system increases to 100 %, the solubility of gas in the condensate increases from 118.3m^3/m^3 to 74.8 m^3/m^3, and the amount of condensate dispersed in the gas increases from 35.8 g/m^3 to 6.4 decreases to g/m^3. This result obtained is consistent with the results we obtained in the previous chapters, that is, the working agent must have a high solubility in that liquid in order to disperse any liquid and keep this dispersed phase more stable in the dispersed medium.

If the precipitated condensate is treated with natural gas, 23% condensate is obtained as a result of 4 cycles, while with 100% nitrogen, it is only 8%. However, despite this, two positive features of nitrogen have emerged for its use as a working agent: 1) its composition of 20-30% in the gas mixture has relatively little negative effect on the dispersion of condensate; 2) the amount of condensate vaporized with nitrogen is almost the same, depending on the cycles during the repeated action.

Based on these results, the effect of nitrogen gas on the retrograde condensation pressure of hydrocarbon mixtures was considered, and it was found that the retrograde condensation pressure of the gas condensate system increases when the amount of nitrogen increases to 40-50% in the temperature range of 15-115 °C, but when the amount of nitrogen exceeds 40-50%, this a decrease in the price of pressure was observed. Since the results obtained in these studies are of interest due to their physical and thermodynamic nature, the studies were continued, and the crisis parameters of the given nitrogen-containing gas condensate system were calculated using a special calculation program. It was found that the crisis temperature and crisis volume of the system decrease as the amount of nitrogen increases. The calculated crisis parameters were solved together with the experimental data and an empirical equation was obtained that allowed to calculate the phase diagrams of these systems in a wider range of temperatures. It was determined that the retrograde condensation pressure of a natural system with nitrogen mixture has a different character depending on the temperature interval. The physical essence of this effect is that with an increase in the amount of nitrogen in a given mixture, the P-T phase diagram of that mixture accumulates to the left - towards the individual P-T phase diagram of nitrogen (graph 5).



Graph 5. Phase diagrams of nitrogen-containing natural gas mixture

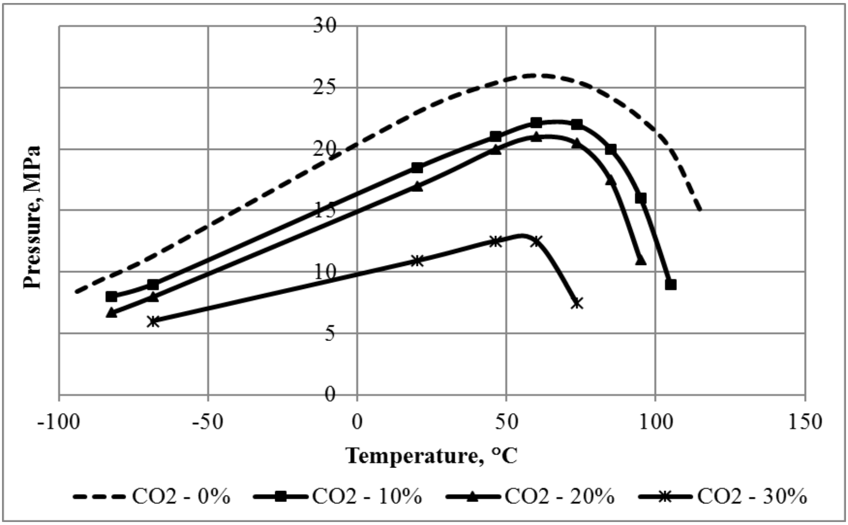
However, since the amount of heavy components in the taken system remains constant and the increase of nitrogen is obtained due to the replacement of gas components, the phase diagrams of the system have different characteristics with the increase of nitrogen. In other words, nitrogen gas affects only the properties of the dispersed medium and changes the stability of the system differently depending on the temperature range.

In the next studies, the issue of removing carbon dioxide by evaporating the condensate deposited in the formation and in the well bottom zone was studied. Based on research, it was determined that carbon dioxide has a higher ability to evaporate condensate due to its better solubility in condensate than other gases. It should be noted that here the effect of this component on the phase transformations of the gas condensate system is determined to be one of the most important factors. Taking this into account, the experimental studies conducted with nitrogen were also repeated with CO_2.

From the obtained results, it is known that the increase of carbon dioxide in the gas mixture from 0 to 30 % increases the amount of condensate dispersed in the gas phase from 35.8 to 42g/m^3. This is also confirmed by the ability of the gas to disperse the hydrocarbon condensate well, and the increase in the amount of gas dissolved in the condensate phase. An increase in the amount of CO_2 in the gas phase up to 30 % leads to an increase in the amount of gas dissolved in a unit volume of condensate from 118.3 to 145 g/m^3. With natural gas, 23 % is recovered as a result of 4 cycles, and if the precipitated condensate is re-produced, with a gas mixture containing 30% CO_2, this result is 33%. However, increasing the number of cycles reduces the amount of vaporized condensate. This can be explained by the reduction of light fractions in the condensed condensate.

At the same time, it was evaluated how carbon dioxide affects the phase transition processes, especially the retrograde condensation pressure. For this, the crisis parameters of the system containing carbon dioxide, as well as with nitrogen, were calculated using experimental data, and appropriate phase diagrams were constructed based on this (graph 6).

It is known that regardless of the value of the crisis pressure of the system in which CO_2 enters, it tries to reduce the value of that pressure. Therefore, there is a limit to the increase in the amount of CO_2 in the mixture, after which the crisis pressure of the mixture begins to increase, that is, the crisis pressure of the system approaches the crisis pressure of CO_2.



Graph 6. Phase diagrams of natural gas mixture containing CO_2

It can be concluded from this that the influence of nitrogen and carbon dioxide on the retrograde condensation pressure of gas condensate systems cannot be unambiguously evaluated. The retrograde condensation pressures of such mixtures can be different in different temperature ranges due to the change of system properties and crisis parameters. Therefore, it is important to take into account the above-mentioned factor, as regular changes in the composition of the formation system are observed during the evaporation of the condensate deposited in the formation with such gases.

The effect of the physical properties of the working agent on the efficiency of the method of evaporation of condensate with gases of different composition was also studied. Studies were conducted in a standard PVT bomb with seven different gas mixtures containing different amounts of non-hydrocarbon gases (CO_2 and N_2). Using the given thermodynamic and physical parameters characterizing these gas mixtures - crisis temperature, crisis pressure, acentric factor, absolute and relative densities, compressibility coefficient, the parameters of greater importance in the evaporation of the precipitated condensate of working agents with different compositions were evaluated, which is retrograde condensate and made it possible to select an efficient working agent for vaporization and control its necessary parameters.

It was found that an increase in the crisis temperature of the working agent, a decrease in the crisis pressure and the crisis compression ratio improves its ability to evaporate the precipitated condensate, but the dependence of the amount of evaporated condensate on the crisis volume of the working agent cannot be unambiguously estimated. A high critical temperature of the absorbed component means that it approaches liquid properties. Therefore, components with more liquid properties keep the dispersed phase more stable. This, of course, can be associated with high molecular and internal friction forces.

An increase in the relative density of a gas increases its ability to disperse a liquid or retain a dispersed phase, because the increase in density increases the number of molecules in a unit volume. The acentric factor of the working agent affects the amount of evaporated condensate and causes its increase.

The critical parameters of the working agent used in vaporization of precipitated condensate are important factors that carry the main information about its efficiency. By calculating the critical temperature, pressure, and compressibility factor at the critical point of the given gases and comparing the obtained values, the ability to vaporize the retrograded carbon-hydrogen condensate and keep the dispersed phase in suspension can be estimated in advance.

Re-production by impacting the settled condensate with natural gas was also studied in the reservoir model. Dispersion of porous medium and residual water with "dry" natural gas of settled condensate was considered separately.

Comparison of the results obtained while studying the effect of the porous medium with the results obtained in the PVT bomb, taking into account the study of the effect of porosity - m (unit fraction), temperature - t (°C), condensate density - ρ (kg/m^3) and the amount of residual water - φ (%) on the process taking, in order to optimize the number of experiments, the method of combination squares was used. Dependencies between these parameters were determined and the following expression was obtained:

$$\gamma = \frac{0{,}36}{19{,}124m - 2{,}63} - 0{,}01(0{,}1\varphi + 1)^2 - 0{,}015\rho + 0{,}025t + 10{,}09 \qquad (12)$$

The relative error of this expression was calculated and it was determined that the relative error does not exceed 3% in the variation interval with the given parameter. Based on this, the given statement can be considered satisfactory.

In the reservoir model, after differential condensation is complete at 6 MPa, gas is injected into the reservoir and the pressure is increased to 8 MPa. After the recovery of thermodynamic equilibrium state, it is again differentially condensed up to 6 MPa.

While studying the effect of the porous medium on the differential condensation process, the physical and chemical properties of the gas condensate phase extracted at each step of the pressure drop were studied. The amount and density of extracted condensate, the amount of separation and degassing gases, their component composition and densities were determined.

As a result of the conducted studies, it was found that the decrease in the porosity of the formation or the increase in the specific surface area reduces the amount of produced condensate. Thus, the reduction of the porosity coefficient from 0.4 to 0.19 reduces the amount of produced condensate by 25 %. On the other hand, it was found that the effect of increasing the porosity after 30% on the process is not noticeable.

Temperature has a positive effect on the dispersion of retrograde precipitated condensate. Thus, when the temperature increases from 70 °C to 110 °C, the amount of condensate produced by dispersing increases by more than 50 % in the PVT bomb and 30% in the layer model in accordance with the linear law. At the same time, increasing the temperature in a given interval reduces the difference between the dispersion occurring in the layer model and the PVT bomb.

An increase in the density of the condensate part of the initial bed from 720 kg/m^3 to 780 kg/m^3 reduces the amount of condensate dispersed and produced from the formation model due to the impact with natural gas by 25 %, and as a result of the surface adsorption relations in the formation model compared to the PVT bomb, this indicator has decreased by more than 2 times happens.

The fifth chapter is dedicated to the improvement of the most widely used and most efficient irrigation method for increasing the component yield of gas condensate and gas condensate oil fields for application in the fields in the final stage of exploitation.

It is known that the development of gas condensate deposits with high formation pressure and temperature is designed without taking into account the methods of additional influence. The main reason for this is that in such thermobaric conditions, methods of impacting the formation require large funds and complex surface equipment. However, exploitation of gas condensate fields in natural mode leads to a number of complications due to retrograde processes and the loss of hydrocarbon condensate of great industrial importance in the formation. At the last stage of the development, a sufficient reduction of formation pressure and saturation of the deposit with more than 60 % settled liquid condensate necessitates the application of artificial impact methods. At the same time, these thermobaric conditions make it possible to seriously affect the final condensate yield by exploiting the field with artificial methods like a light oil field.

Against the background of the decrease in reservoir pressure, the sharp increase in saturation due to liquid condensate, and the sharp decrease in relative phase permeability due to gas, it is considered more appropriate to process gas condensate fields in the final stage of development, like light oil fields, by artificial impact methods on the formation. Experience shows that in light oil fields with reduced formation pressure, due to the ratio of viscosities of compressing and compressed fluids being very close to unity, the most efficient method of influence to increase the oil yield coefficient is the watering method. However, it is not possible to ensure the piston-like movement of the water contour due to the change of permeability in gas condensate deposits in a large interval from 5 mD to 100 mD. The zonal inhomogeneity of the layers creates the basis for water to find its way to production wells faster, even in small depressions in high permeability areas. In such zones, areas with poor permeability are not affected, and even at high depressions, it is difficult to ensure the movement of oil or condensate towards production wells. When the bed consists of non-homogeneous layers with different permeability, the coverage coefficient of irrigation decreases and the process gives only a short-term positive result.

In the final stage of development, the gas condensate fields with sharply reduced formation pressure are treated like light oil fields by the method of artificial impact on the formation and to achieve complete coverage of the formations with the injected water, including non-homogeneous lens-like areas, the movement of injected water in the high permeability areas of the formation a new technology has been developed that restricts and directs to areas of poor permeability. For this purpose, a special polymer-dispersed system was prepared using polyacrylamide and clay samples taken from the Dash Salahli bentonite deposit of Azerbaijan.

The quality of clays for the preparation of polymer-dispersed systems is determined by: the amount of montmorillonite, a mineral that forms bentonite, is more than 70 %, the effective viscosity of the suspension is more than 30 mPa·s, it maintains its thermostability up to 200 °C, its swelling capacity is 20- Due to meeting the requirements such as more than 30 units, it was considered appropriate to use Dash Salahli clay with nanoparticles in conducting laboratory experiments.

A cylindrical pipe with a length of 1500 mm and a diameter of 30 mm was used as a layer model to test the efficiency of the working agent with a new composition in laboratory conditions. The cylindrical layer model is filled with a mixture of quartz sand and quartz dust (ash). In the first experiment, the permeability of the layer model was $267 \cdot 10^{-15}$ m^2, and the porosity was 26 %. All experiments used light oil with a viscosity of 6 mPa·s, a density of 805 kg/m^3 and potable water as injection water, without considering residual or formation water.

The set problem is the displacement of residual condensate in the formation with water

since the research was solved as water-oil systems. Parameters such as the length of the L-layer model, k, m - permeability and porosity of the porous medium, ΔP - pressure difference created in the model, μ - viscosity of oil, σ - surface tension and υ - percolation rate to determine the similarity criteria of the reservoir model in the specified directions π_1 and π_2 factors were determined based on the automodel values (0.5 and 0.5×106, respectively).

$$\pi_1 = \frac{\sigma}{\Delta P_{min}\sqrt{\frac{k}{m}}} \text{ and } \pi_2 = \frac{\sigma L_{min}}{k\Delta P_{min}} \tag{13}$$

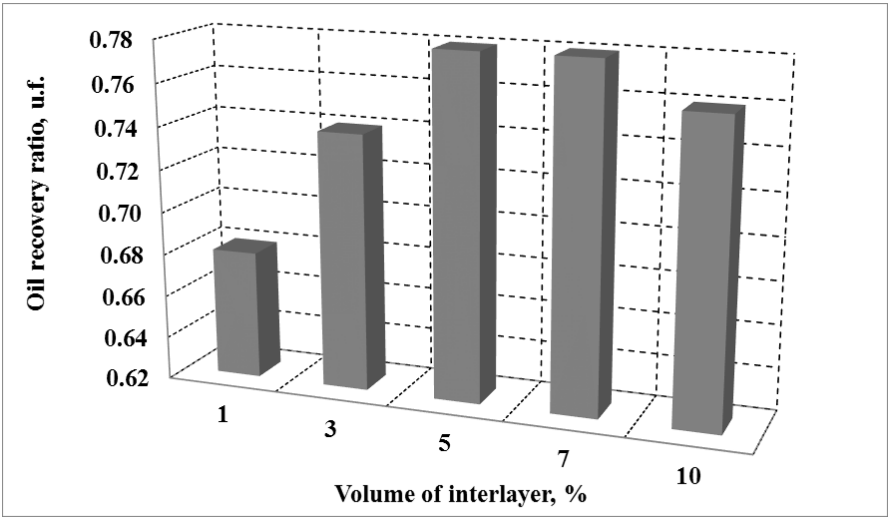
The minimum and maximum values of the parameters under the specified conditions were calculated based on expressions (13).

The reservoir model is filled with light oil. After the complete saturation of the model with oil is confirmed, the stability of its temperature (room temperature) is ensured. After that, the compression of oil with potable water is started under the conditions of stable thermodynamic parameters and at the difference of fixed pressures. The process is continued until the obtained product is 100% diluted. Thus, the necessary measurements are specified and the first stage of the experiment is considered completed.

In the second stage, the process of compressing the product with potable water based on the received product in the 100% fluidized bed model is continued again, keeping the same temperature, pressure difference, inlet and outlet pressures constant. But this time, initially, a clay solution prepared with Dash Salahli clay in fresh water in a specified amount (10% solution) is injected in the form of interlayer. After that, a specified volume of polymer consisting of potable water and polyacrylamide (0.5% solution) is injected as a continuation of the system, and then the compression process is continued until the product obtained with the same potable water is 100 % hydrated. Despite the 100 % dilution of the product obtained at the end of the first stage (oil yield – 32 %), after injecting the polymer dispersion system into the formation model in the form of intermediate layer, its oil yield increases dramatically. So, after the product obtained in the second stage is 100 % watered, the final oil yield coefficient of the "layer" is equal to 78 %.

One of the main issues during the research is the determination of the optimal volume of the injected alcohol. It is known that if the volume of interlayer during impact on the formation leads to an increase in the cost of the additional product obtained from the formation, of course, it will have a negative effect on the efficiency of the general method. Therefore, this factor should be studied as one of the main requirements for the proposed method. Therefore, the compaction process was carried out in a comparative manner in a 5-layer model with the same properties. First, the first stage of compaction (100% dilution of the resulting product with potable water) is completed in the same way in each layer model. Then, different amounts of 0.01, 0.03, 0.05, 0.07, and 0.1 volumes of porous media of 10% solution of Dash Salahli clay are injected into each layer model, but the volume of polymer (polyacrylamide) solution (0.1 per volume of porous medium) and its density (0.5% in drinking water) were kept constant. Thus, the second stage of compression is completed in the manner described above. At the end of the process, the final oil yield coefficients of all five models were determined. According to the results, it was found that the final oil yield coefficient increases with the increase of the volume of intermediate layer up to 5%. However, the increase in the volume of intermediate layer from 5% to 7% does not have any effect on the price of the oil yield coefficient. The subsequent increase in the volume of intermediate layer has a negative effect on the process (graph 7).

As a result of experiments, the effectiveness of applying a polymer dispersed system consisting of the following components to



Graph 7. Influence of the volume of the intermediate layer on the efficiency of the process

eliminate the inhomogeneity of the layers due to permeability and to expand the scope of injected water in the gas condensate or gas condensate oil fields in the final stage of development was determined:

Polyacrylamide (polymer) with 0.5-1.0 volume %

Stone Salah bentonite clay with 4.0-8.0 volume %

Remaining drinking water

Based on the research conducted in the simple formation model, it was determined that the irrigation conducted by applying polymer dispersion tar made of a mixture of Dash Salahli clay and polyacrylamide with a special composition can increase the oil yield of the "lay" from 32% to 78% compared to the usual irrigation method.

According to the experiments conducted taking into account the heterogeneity of the reservoir, the introduction of the proposed interlayer increases the coverage of water by regulating the movement of the oil-water contact during irrigation and reduces the negative effect of the heterogeneity of the reservoir by 4.7 times.

CONCLUSION

1. As a result of the conducted studies, gas-condensate mixtures are considered as dispersed systems and the importance of studying their phase relations in the layer model has been proven, and the differential condensation method has been substantially improved, the rate of pressure drop does not affect the thermodynamic equilibrium state, and the transition value to the automodel region (<1,66×10^{-3} MPa/sec) is set.

2. Based on the data of a number of gas condensate fields operated in depletion mode, the parameters affecting the phase state of the dispersed layer system during differential condensation, the interval of their change and the criteria of similarity were determined, and a special experimental device and methodology for the study of the processes of depletion of gas condensate fields and production of precipitated retrograde condensate was created.

3. Summarizing the results obtained from the theoretical and experimental studies, the complications arising during the exploitation of gas condensate fields in the depletion mode: 1) reservoir pressure and temperature; 2) physical properties of the dispersed phase and medium; 3) mutual relations of gas and liquid phases; 4) composition of the layer system; 5) properties of the porous medium; 6) classification is given taking into account factors such as the amount and properties of groundwater.

4. The pressure dependence of the condensate factor of the formation system $K=f(P)$ during the depletion of the deposit was investigated theoretically and experimentally. For the cases $K>1$, $K=1$ and $K<1$, the pressure-dependent transition points of the layer system have been detected. Thus, the conditions of gas in liquid ($P \geq P_{dhd}$), liquid gas ($P_{rk} \leq P \leq P_{dhd}$) and transition to two-phase (condensate and gas) state ($P \leq P_{rk} \leq P_{dhd}$) are determined.

5. The proportionality coefficient (α_p) between the condensate factor of the formation system and the formation pressure and its physical essence were evaluated. It was found that this parameter characterizes the stability of the dispersed state of the layer system.

The retrograde and maximum condensation pressures of the gas-condensate mixture were determined based on the dependence of $\alpha_p = f(P)$) with special studies.

6. According to the studies carried out in the reservoir model, it was determined that the temperature increase in the reservoir can occur according to isobaric and isochoric processes. In the first case, the potential energy of the pressure (*PV*) increases due to the expansion of the volume, and in the second case, the internal energy and technical work (*VdP*) increases due to the increase in pressure. In both cases, the stability of the dispersed phase in the system increases. On the other hand, the increase in temperature increases the surface energy and decreases the surface tension at the contact surface of the condensate-gas-rock phases. This slows down retrograde condensation. Therefore, according to experimental studies, a 1.5-fold increase in temperature reduces the difference of the final condensate yield obtained in the PVT bomb with the layer model by more than 2 times.

7. According to the studies conducted in order to investigate the effect of formation water on the depletion mode of the field, the increase of water saturation in the formation model up to 40% depends on the values of condensate density, porosity and temperature, and the total amount of condensate produced can be reduced to 32% due to the increase of the retrograde condensation pressure of the system and the increase of the liquid-gas ratio. However, since part of the water is produced by evaporation during depletion, the rate of pressure drop decreases and leads to a decrease in condensate loss.

8. The research materials of exploitation of gas condensate deposits by the "gas cycling" method were analyzed, the shortcomings of the method were investigated, ways of improving the method were shown, and a method of partially maintaining the reservoir pressure was proposed. Theoretical and special procedure studies show the advantages of this method: 1) increasing profits by giving a part of the produced gas to users; 2) ensuring continuous operation of the gas injection system by reducing the gas injected

into the formation; 3) reduction of formation pressure leads to reduction of working pressure, current and capital maintenance costs of technological facilities; 4) reducing the volume of condensate per unit volume of gas and, as a result, improving the dispersion of hydrocarbon liquid; 5) reduction of the retrograde condensation pressure of the formation system and management of its single-phase state; 6) it has been proven that it is possible to completely stop the gas injection process at a certain moment of field operation and continue operation in gas mode.

9. On the basis of the experimental data, it was concluded that the influence of the gas mixture on the layer system with retrograde condensation "beginning of intensive condensation" in the pressure interval - $|P_{Rk}\ P_{İk1}|$ starting is more efficient and by starting formation gas injection at the specified interval, maximum condensate and gas production can be achieved with proper management of formation pressure drop rate and volume of injected working agent.

10. In order to increase the effectiveness of the method of partially maintaining reservoir pressure, special experimental studies were conducted, the requirements for the working agent and the principles of selecting an effective working agent were defined, and a more efficient non-hydrocarbon natural gas mixture was proposed.

11. Ways to increase the efficiency of the working agent during impact on the well bottom zone were studied and the following results were obtained:

1) It was determined that the retrograde condensation pressure of the gas condensate system with nitrogen gas mixture has a different character depending on the temperature interval. The physical nature of this effect, which contradicts previous results, was investigated. It was found that if nitrogen gas is used for processing the bottom zone of a gas condensate well, its efficiency should be determined depending on the degree of saturation of the well with retrograde condensate, the amount of nitrogen in the working agent, the formation temperature and the number of cycles affecting the well.

2) It was determined that the increase in the amount of CO_2 in the gas phase up to 30% leads to an increase in the amount of gas dissolved in a unit volume of condensate from 118.3 to 145 g/m^3. For this reason, carbon dioxide surpasses natural gas in its ability to disperse precipitated condensate, as a result of 4 cycles with natural gas, 23 %, if the precipitated condensate is regenerated, 30 % with a gas mixture containing CO_2, this result is 33%. But this effect depends on the number of cycles. On the other hand, it is known that the increase of carbon dioxide in the natural hydrocarbon system after a certain value (in the range of 70-80 % in this case) increases the value of the crisis pressure of the system.

3) It was determined that an increase in the crisis temperature of the working agent, a decrease in the crisis pressure and the crisis compression ratio improves its ability to disperse the precipitated condensate, but the dependence of the amount of evaporated condensate on the crisis volume of the working agent cannot be evaluated unambiguously.

4) It was found that the degree of mutual solubility of phases should be taken into account when choosing a working agent. For example, it is known that as the amount of paraffinic components in a hydrocarbon liquid increases, the amount of dissolved gas under given thermobaric conditions also increases. An increase in aromatic hydrocarbons in the condensate content, on the contrary, leads to a decrease in dissolved gas. Such factors are important factors in the condensate dispersion process.

12. Conducted studies have revealed that formation environment affects the vaporization of deposited condensate with working agent. The following main results were obtained from the conducted experimental studies:

1) A decrease in formation porosity (from 0.4 to 0.19) and an increase in specific surface (from $87 \cdot 10^3$ m^2/m^3- to $660 \cdot 10^3$ m^2/m^3) reduces the amount of produced condensate (up to 25%). On the other hand, it was found that the effect of increasing the porosity after 30% on the process is not noticeable.

2) Temperature has a positive effect on the dispersion of retrograde deposited condensate. Thus, when the temperature increases from 70°C to 110°C, the amount of condensate produced by dispersing increases by more than 50% in the PVT bomb and more than 30% in the layer model in accordance with the linear law. At the same time, it was found that the increase in temperature in the given interval reduces the difference between the formation model and the dispersion occurring in the PVT bomb, and as a result, the proportion of condensate production from these environments decreases by more than 2 times as a result of the impact with natural gas;

3) It was found that the increase of the condensate density in the bed from 720 kg/m^3 to 780 kg/m^3 at the initial moment reduces the amount of condensate dispersed and produced from the formation model due to the impact with natural gas by 25%, and as a result of the surface adsorption relations in the formation model compared to the PVT bomb, this the indicator decreases more than 2 times.

13. It was determined that any limit of water saturation of the porous medium has a negative effect on the vaporization of condensate with natural "dry" gas, but this can vary depending on its physical-thermodynamic state (water in the vapor phase, in close contact with the surface of rock grains, and in the free liquid phase). On the other hand, the decrease in density of the condensate, increase in porosity and temperature weakens the effect of residual water on dispersion.

14. In the last stage of development of gas condensate or gas condensate oil fields, a new watering method was proposed by applying a polymer dispersion vodka made from a mixture of Dash Salahli clay and polyacrylamide with a special composition for the production of liquid hydrocarbon that remains in the formation and is difficult to extract, and it was determined that this method " can increase condensate yield" from 32% to 78% compared to the usual irrigation method.

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Personal contribution of the claimant in the works performed

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