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# ABSTRACT

of the dissertation for the degree of Doctor of Technical Sciences

# MODDELING OF DEEP GAS CONDENSATE DEPOSITS BY TAKING INTO ACCOUNT THE SPACE STATUS OF LAY PROCESS FLUIDS IN EXPECTATION WITH GAS AGENTS

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| Field of science: | Technical Sciences |
| Applicant: | **Mubariz Sevdimali Khalilov** |

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|---|---|
| **Scientific consultant:** | doctor of technicalscience<br>**Xasay Azay Feyzullayev** |
| **Official opponents:** | doctor of technical sciences, professor<br>**Tofiq Alovsat Samedov** |
| | doctor of technical sciences<br>**Mahir Abdulali Rasulov** |
| | doctor of physical and mathematical sciences, professor<br>**Hamlet Farman Quliyev** |
| | doctor of technical sceiences<br>**Fuad Faiq Mammadov** |

Dissertation council ED 2.03 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at the Azerbaijan State Oil and Industry University.

| | |
|---|---|
| Chairman of the Dissertation council: ____________ | Doctor of Technical Sciences, Associate Professor<br>**A. A. Suleymanov** |
| Scientific secretary of the Dissertation council: ____________ | Doctor of Philosophy in Technology, Associate Professor<br>**Y.Y.Shmoncheva** |
| Chairman of the scientific: ____________ | Doctor of Technical Sciences, Professor<br>**A.M.Mammad-zadeh** |

**I confirm the signatures**
**Scientific Secretary of ASOIU,**
**Associate Professor** **N.T. Aliyeva**

# GENERAL CHARACTERISTICS OF THE WORK

**The relevance of the topic and the degree of processing.**

Experience in the development of oil and gas condensate and gas condensate fields shows that the extraction capacity of oil, gas and gaseous liquids is quite low, and as a result, the volume of oil, gas and gaseous liquids remaining in the Earth's crust is constantly increasing. Hydrocarbon reserves with extraction complications are mainly retrograde condensate accumulated in depleted gas condensate fields, as well as hydrocarbon reserves of oil-bearing gas condensate fields and liquid hydrocarbons accumulated in gas-saturated parts of these fields etc.

Currently, the hydrocarbon reserves of non-extracted oil, gas and gaseous liquids are estimated at billions of tons, and gas and hydrocarbon reserves at trillions of cubic meters. All this is one of the most important issues in the development of new complex methods of development and their scientific substantiation, which will increase the efficiency of extraction of hydrocarbon resources from natural oil and gas condensate and gas condensate fields.

Finding optimal options for extraction of natural hydrocarbon resources Mathematical modeling of formation systems and formation processes and based on it to evaluate the advantages and disadvantages of the application of multiple methods of development of strata containing gas and liquid hydrocarbons, as well as the complexity of the physical processes of extraction emphasizes the need for complex scientific approaches in the selection and creation. The most important direction of this research is the study of the mechanisms of mass transfer and interfacial transition of hydrocarbons, taking into account capillary forces and pressure gradients in unbalanced multiphase flow in porous media, the problem of technical implementation of methods proposed by fundamental research in physical and mathematical modeling conditioned by necessity.

The study considers the possibility of solving the above-mentioned important issues of oil and gas condensate and gas condensate development, as well as methods of physical and mathematical modeling of formation processes and the creation of hydrothermodynamic bases for different types of impacts on productive strata, including increasing condensate yield screen with hydrocarbon and non-hydrocarbon gases, gas-water mixture, as well as various compression agents at the level of oil-gas contact (injection, polymer water mixture, binder polymer, foam system, water-gas mixture, thermogas, etc.) The issues of preventing the ingress of gas into the oil mixture have been resolved by forming the formation of also, an algorithm for solving appropriate development problems and the development of their computer programs were 1implemented.

**The purpose of the work** is to conduct a comprehensive theoretical study of modeling methods of formation processes taking into account the phase state of liquids in the interaction of gas and liquid condensate fields with gaseous and liquid agents, to develop new methods to increase the efficiency of liquid hydrocarbon resources.

**The main issues of the study:**

1. Modeling of the process of processing gas condensate under the influence of liquid and gas in different processing modes.

2. Modeling the process of oil well development by forming a screen with various compressors at the level of the oil and gas contact line of the oil and gas condensate layer.

3. Solving and researching the issues of the process of development of the multilayer gas condensate field.

4. Solution and investigation of leakage problems of high pressure gas condensate development process based on wellhead data

5. Solving the problem of identification of leak-holding properties of gas condensate and oil and gas condensate layer in different development modes.

**Research methods.** The tasks of the dissertation were solved using the theory of hydrodynamics, computational mathematics, optimal control problems, inverse problems, modern methods of mathematical physics, modern information technologies and software.

**Scientific innovations.** The complex researches carried out and the generalization of their results allowed to obtain the following scientific innovations:

1. Theoretical base and algorithm have been developed and software for forecasting technological parameters of development has been developed, which allows to model the process of impact on the gas condensate layer with water-gas mixture and liquid hydrocarbons at pressures below the maximum condensate pressure.
2. Methods for calculating the problems of intensification of retrograde condensate extraction in the development of the well bottom zone of gas condensate wells with light fractional hot hydrocarbons have been developed.
3. A methodology has been developed that allows to regulate the effective development of the oil mixture when exposed to liquids and gases in the oil and gas condensate layer in different processing modes.
4. Theoretical base and algorithm allowing to model the process of development of multilayer gas condensate fields with the same network of wells have been developed and software for forecasting technological indicators of development has been developed.
5. Calculation methods have been developed that allow to predict the technological parameters of the process of development of anomalous high-pressure gas condensate layer on the basis of wellhead data.
6. Methods of parametric identification of hydrodynamic models of development of gas condensate layer with water pressure regime with variable setting have been developed.

**The main provisions for the defense.**

1. Solve and study the problems of the process of development of the gas condensate layer under the influence of liquid and gas in different processing modes.

2. Solution and algorithm of problems of process of development of oil and gas condensate layer, its program realization.

3. Methods of solving problems of the process of development of multilayer gas condensate field.

4. Methods of solving the problems of filtration of the process of development of high-pressure gas condensate layer according to the wellhead data.

5. Method of parametric identification of hydrodynamic models of development of gas condensate layer with water pressure regime with variation.

**Practical significance of the work and realization of results**. The proposed research is aimed at developing new scientific methods based on modeling the interaction of liquids and gaseous agents in the formation to increase the component yield of gas condensate and oil and gas condensate layers, as well as scientific and methodological basis for assessing technical and technological indicators of gas condensate and oil condensate fields are experimentally aimed at important studies.

It is proposed to use the scientific innovations obtained in the dissertation to increase the efficiency of development in the analysis and design of gas condensate and oil and gas condensate fields.

**Approbation of the work**. Discussion of the main provisions and results of the dissertation:

- At the International Conference on "Problems of cybernetics and informatics" PCI 2012 (September 12-14, Baku, 2012);

- At the VII International Scientific Conference on "Modern Achievements of Science" (October 23-24, Baku, 2014);

- At the seminar of the section "Development of oil and gas fields" of the Institute of Geology and Geophysics of Azerbaijan National Academy of Sciences (Baku, 2015);

- In the scientific seminars of the department "Development and operation of gas condensate fields" of Azerbaijan State University of Oil and Industry (Baku, 2013-2016);

- Academician A.N. on "Mathematical modeling of processes and systems" V International scientific-practical conference dedicated to the 110th anniversary of Tikhinovat the conference, (November 17-19, Sterlitamak, 2016);

- “Actual issues of theoretical and applied mathematics” at the Republican scientific conference dedicated to the 100th anniversary of academician M.L.Rasulov (October 28-29, Sheki, 2016);

- At the conference "Actual problems of mathematics and mechanics" dedicated to the 100th anniversary of Goshgar Ahmadov, (2017, Baku, Azerbaijan);

- At the International scientific-practical conference on "Modern mathematics and its applications" (May 18-20, Ufa, 2017)

- At the V International Conference on "Control and optimization with industrial applications" COIA2018, (July 11-13, Baku, 2018)

- At the 18th FIFAC Conference on "Technology Culture and International Stability" (September 13-15, Baku, 2018);

- “Non-local issues and physics, computer science, etc. Problems ”V International Scientific Conference, (Nalchik-2018, Russia);

- At the IX International Scientific-Practical Conference on "Mathematical Modeling of Systems and Processes" (2019, Ufa, Russia);

- At the VII International Conference on "Control and optimization with industrial applications" COIA2020 "(27-28 August 2020;

- At the VIII International Conference on "Control and optimization with industrial applications" COIA2022 "(24-26 August 2022;

**In scientific seminars.** - In the seminar of the section "Development of oil and gas fields" of the Institute of Geology and

Geophysics of Azerbaijan National Academy of Sciences (Baku, 2015), in the scientific seminars of the department of "Development and operation of gas condensate fields" of Azerbaijan State University of Oil and Industry ( Baku, 2013-2016), at the Scientific Research Institute of Applied Mathematics at Baku State University, in the scientific seminar of the Faculty of Applied Mathematics and Cybernetics of Baku State University.

**Application of work.** The conducted studies are of practical importance for the development of scientific and methodological foundations for the regulation and management of gas, gas condensate and oil and gas condensate fields.

It is proposed to use the scientific developments obtained in the dissertation to improve the efficiency of development in the analysis and design of the development of gas, gas condensate and oil and gas condensate fields.

**Scientific publications.** According to the dissertation, 35 scientific papers were published, 24 articles, including 4 published in foreign countries, and 13 papers were published in materials and abstracts of international and local conferences. 7 articles are in the Web of Science, Emerging Sources Citation Index, Scopus international database.

**The name of the organization in which the dissertation work has been carried out.** The dissertation work was carried out at the Institute of Geology and Geophysics of National Academy of Sciences of Azerbaijan.

**The volume and structure of the dissertation.** The dissertation consists of an introduction, 7 chapters, the main results of the work, a list of 196 references. The total volume of the work is 281 pages, and the main volume is 278 (414491) pages, including 61 figures and 11 tables. In particular, Chapter 1-62332, Chapter 2 - 59719, Chapter 3-36000, Chapter 4-52000, Chapter 5-52000, Chapter 6-60000, Chapter 7-36000, The result is 3577 characters.

## CONTENT OF THE WORK

In the introductory part, the relevance of the dissertation topic is substantiated, the subject of research, scientific innovations of the work are explained, and the main results are given.

**The first chapter** reviews the problems of modeling the phase state of a gas-liquid mixture and reservoir processes in the development of gas condensate and oil and gas condensate fields and gives an overview of the work related to the analysis of studies to increase the flow rate of condensate and oil fields, the necessity of studying a certain group of issues that are important in the exploitation of hydrocarbon resources is substantiated.

Numerous works on hydro-gas-dynamic modeling of the development of oil, gas condensate and oil and gas condensate fields and studying the possibilities of increasing production through oil and condensate have been dedicated by researchers M.T.Abasov, S.N. Buzinov, A.I. Bruysilovski, A.I.Grichenko, G.R.Gurevich, B.M.Entov, S.N.Zakirov, G.A.Zotov, Y.P.Koratayev, A.M.Guliyev, S.A.Kundin, A.H.Mirjazanzade, E.M.Minski, V.S.Mitlin, V.N.Nikolaevsky, G.V.Rassokhin, G.S.Stepanova, A.I.Shirkovsky, G.P.Chubilski, Y.P.Zaychev, T.M.Shmiglya, Z.Y.Abbasov, Q.I.Calalov, A.M. Mammadzada., T.A .Samadov, M.A.Rasulov, A.A. Suleimanov, X.A.Feyzullayev and others innovative methods have been developed and presented for practical application.

The process of complete filtration of gas condensate and gas-oil-condensate mixture in a reservoir can be described within the framework of the general theory of filtration of multicomponent fluids. Filtration equations for a multicomponent fluid that determine the state of the mixture in all cases of filtration, including cases when the formation pressure is greater or less than the initial condensation pressure, and solving problems of thermodynamic equilibrium of phases, finding the composition and phase saturation of functions, and using calculation methods to determine the physical properties of the mixture allows do it.

The filtration equations for a multicomponent liquid contain a fairly large amount of information and require the introduction of a number of closing relationships when applied to solving many practical problems. First of all, this is due to the mathematical modeling of the phase state of a real mixture and its inclusion in the filtration equations with a certain accuracy.

One of the main problems in mathematical modeling of the phase state of a real mixture is that it can be adequately replaced by an artificial mixture with a small number of components. In this case, individual fractions of the hydrocarbon system, simulating a real gas condensate system, are replaced by some pseudo-components. The most difficult part of modeling a hydrocarbon reservoir system is combining individual fractions of a real system into pseudo-components and determining the properties of these pseudo-components. With this approach, to a certain extent, freedom of action is created for the choice of mixture pseudo-components and the computational study of various processes associated with the gas condensate system during its production, and it is also possible to vary the properties of the pseudo-components within fairly large limits. That is, the values of the main parameters of the pseudo-components differ from those found in natural individual hydrocarbons.

The combination of each individual hydrocarbon in pseudo-components is often based on an empirical approach. Accurate modeling of $C_1 - C_4$ hydrocarbons with a fairly large number of pseudo-components, as well as $CO_2$, $H_2S$, without any changes in the components, is presented as a model mixture. Sufficiently heavy $C_{5+}$ components are replaced by pseudo-components.When a real system is modeled with a three-component mixture, one of the pseudo-components is $C_1$, $C_2 - C_4$ hydrocarbons are the second, and $C_{5+}$ is the third pseudo-component. The description of the hydrocarbon fraction of the group is one of the most difficult issues.The description of the hydrocarbon fraction of group $C_{5+}$ is one of the most difficult issues. Adequate replacement of these hydrocarbons with a small number of pseudo-components significantly increases the accuracy of the phase calculations of the natural hydrocarbon system. In this regard, Z.Y.Abbasov, G.I.Jalalov, A.I. Bruysilovski, N.M. Viboronov, A.I.Grichenko, Q.R.Gurevich, Q.S.Stepanova, E.E.Ramazanova, A.Y.Hamiot, R.Rid, T. Sherwood, K.N.Coats, X.A.Feyzullayev and others great attention is paid to their work.

The general approach to determining the parameters of group $C_{5+}$ is based on the fact that their parameters do not change in the conventional division into individual parts with changes in pressure and temperature. Such properties — boiling point, density, and molecular weight — are determined experimentally. The remaining properties are calculated by different correlation dependences obtained experimentally for pure substances. Group $C_{5+}$ is divided into fractions according to the actual boiling point of butane condensate by fractionation. In the absence of fractional separation, the graphical method is applied to the conditional division of group $C_{5+}$. Decomposition of dehumidified condensate into fractions is carried out arbitrarily. In this case, its density, molecular weight and average boilingpoint must be known.

The application of multicomponent fluid filtration equations also requires the development of reliable and efficient calculation methods for determining the thermal physical parameters of real gas-liquid phases. There are two main methods for determining the parameters that characterize the thermal physical properties of phases: the method of determining the supply pressure and the mixture by means of one or another unit state equation.

In the pressure delivery method, the phase equilibrium of the components according to the phases is approximated depending on one parameter that characterizes the pressure, temperature and composition - the supply pressure. The principle of calculation of the supply pressure is that the initial system is replaced by a binary model, and the desired parameter is calculated accordingly. The disadvantage of the method is the mismatch of thermodynamic quantities of the phase density and equilibrium constant. This factor leads to calculation errors in the crisis pressure and temperature regions, as well as at the boundaries of single-phase and two-phase regions.

The approach based on the use of a single state equation for gas and liquid phases has numerous advantages over the closedness of the system of thermodynamic relations described above. The multicomponent properties of real systems are taken into account with the help of parameters of the equation of state depending on pressure, temperature and composition. The study of the thermodynamic Gibss potential determined by the state equation allows to derive (write) the corresponding system equations of phase equilibrium. Such an approach requires finding numerical solutions to a system of nonlinear algebraic equations. Quite accurate solutions Z.Y.Abbasov, A.I. Bruysilovski, B. Sage et al. obtained by using the equation of state proposed in the work, and the calculation of the properties of the liquid and gas phase at high pressures leads to fairly accurate results.

In the system of differential equations expressing the process of multi-phase multi-component filtration, the unknown variables are reservoir pressure and the molar composition of the multi-component mixture. This system of equations makes it possible to determine the state of a multicomponent mixture at reservoir pressure levels above the initial condensation pressure and below and above the maximum condensation pressure, as well as to identify thermodynamically equilibrium phases and physical properties of a multicomponent composition.

The modern level of computer technology has led to a more accurate study of the physical processes occurring in the reservoir, making it possible to solve filtration problems based on multi-phase multicomponent models, and on its basis - the tasks of processing gas condensate and oil and gas condensate deposits, as well as the bottomhole zone of gas condensate wells with gases of different composition, liquid hydrocarbons. At the same time, with the help of variational methods, identification methods have been developed for determining the parameters of the filtration capacity of a multiphase system and the functions of relative phase permeabilities by changing the actual data on the performance of a hydrocarbon deposit. To solve these problems, the works of M.T. Abasov, S.N. Zakirov, Z.U. Abbasov, G.I.Jalalov, X.A.Feyzullayev, H.F.Guliyev deserve special attention.

Despite a large number of studies on the methods of hydrodynamic modeling of the development of gas condensate and oil and gas condensate fields and the creation on their basis of the foundations of various types of methods of influencing productive formations for the development of hydrocarbon resources, improvements in filtration theory in terms of ensuring the adequacy of real physical processes, methodological studies of rational field development hydrocarbons and the development of its theoretical foundations remains relevant as a solution to an important scientific and technical problem.

**In the second chapter**, the problems of estimating the possibility of increasing the condensate yield of the separated gas by forming a mixture with liquid hydrocarbon (ethane) in the pressure range below the maximum condensing pressure in the exhaust gas-condensate layer, solved as well as methods for pumping a water-gas mixture into a gas condensate reservoir operating at depletion under conditions of a pressure range below the maximum condensation pressure, as a result of the redistribution of retrograde condensate deposited in the reservoir along the height under the action of capillary and gravitational forces, the creation of a man-made condensate deposit at the gas-water boundary and the assessment of the possibility recovery of retrograde condensate with a horizontal well drilled into it were solved on the basis of the theoretical base of multicomponent multiphase filtration models.

The main method of processing gas condensate fields is based on the use of energy from natural reservoirs. With this processing method, small costs are required and a sufficiently high gasification coefficient is obtained, but numerous difficulties arise. One of the most serious complications is the accumulation of retrograde condensate in the reservoir and in the well drainage zone and the loss of a large amount of immobile liquid hydrocarbons in the reservoir. In order to prevent this from happening, it is important to periodically apply methods that ensure a decrease in filtration resistance due to gas in the bottomhole zone of a production well at a certain stage of developing a gas condensate reservoir in the depletion mode and to carry out intensifying measures at the wells.

Initially, the possibility of recovering the reserve of liquid hydrocarbons lost in the reservoir (retrograde condensate-$C_{+5}$) due to the sequential injection of ethane ($C_2H_6$) and separated methane gas ($CH_4$) into the gas condensate reservoir at the last stage of processing in the pressure stage was studied in the range below the maximum condensation pressure.

The considered problem

$$\nabla\left[\left(\frac{khf_l(s_l)\rho_l}{\mu_l M_l}x_i\nabla p_l+\frac{khf_g(s_g)\rho_g}{\mu_g M_g}y_i\nabla p_g\right)\right]=$$
$$=\frac{\partial}{\partial t}\left[mh\left(\frac{\rho_l s_l}{M_l}+\frac{\rho_g s_g}{M_g}\right)z_i\right]\pm\sum_{\nu=1}^{s}Q_i^{\nu}(t)\delta(x-x_\nu)\delta(y-y_\nu),$$
$$i=\overline{1,N}, \qquad (1)$$

system of equations and

$$\sum_{i=1}^{N}x_i=\sum_{i=1}^{N}y_i=\sum_{i=1}^{N}z_i=1, \qquad (x,y)\in D, \qquad t\in(0,T)$$

is modeled under appropriate initial and boundary conditions

$$p_g(x,y,t)\Big|_{t=0}=p_{g0}(x,y),\ (x,y)\in D, \qquad (2)$$

$$z_i(x,y,t)\Big|_{t=0}=z_i^0(x,y),\ i=1,2,\dots,N,\ (x,y)\in D, \qquad (3)$$

$$\frac{\partial p_g(\mathrm{x,y},t)}{\partial n}\bigg|_{\Omega} = 0,\ (x, y) \in \Omega.,t \in (0, T). \qquad (4)$$

Here, the unknown quantities are $p_g$ −pressure of the gas phase and the composition of the gas condensate system $z_i$ $i = \overline{1, N}$, $f_g(s_g)$ and $f_l(s_l)$ -relative phase conductivity of the gas and liquid phases, respectively; $s_g$and $s_l$are the coefficients of saturation of the porous medium with gas and liquid phases, respectively; $p_g$, $p_l$- - pressure of gas and liquid phases; $x_i, y_i$- the molar amounts of the $i$ -th component in the liquid and gas phases, respectively; $z_i$- is the total molar amount of the $i$-th component in the mixture; $\rho_g$ and $\rho_l$ are the densities of the gas and liquid phases, respectively; $M_g$ and $M_l$ are the average molecular weights of the gas and liquid phases, respectively; $Q_i^{\nu}(t)$- debit of the ν-th source for the $i$ -th component; $x_\nu, y_\nu$ coordinates of the elementary $\nu$ -th source; s is the number of elementary sources; $\Omega$ - outer boundary of the layer; $k$-absolute permeability, $m$-porosity - the normal (direction) vector drawn to the outer boundary of the $n$-layer; $T$ is the processing time; this is $t$-time.

The dependence between the pressure of hydrocarbon gas-liquid phases and capillary pressure (5) ($p_{clg}$- is the capillary pressure at the liquid-gas interface) is taken into account.

$$p_l = p_g - p_{clg}, \qquad (5)$$

To solve the system of equations

(1)-(5), the parameters $\rho_g, \rho_l,\ \mu_g\ , \mu_l,\quad s_g = 1 - s_l,$
$s_l = \frac{L\rho_g M_l}{L\rho_g M_l + V\rho_l M_g}$ expressing the necessary physical properties of the gas and liquid phases are defined from the following system :

$$\begin{cases} f_{i,l} - f_{i,g} = 0, i = \overline{1, N} \\ x_i L + y_i V - z_i = 0, i = \overline{1, N} \\ \sum_{i=1}^{N} y_i - 1 = 0 \\ L + V = 1 \end{cases}, \qquad (6)$$

Here in the system (6) the first (*N*) number of equations expresses the condition of thermodynamic equilibrium of the volatile components of the gas and liquid phases, and the other (*N* + *2*) number of equations expresses the balance equations of the gas condensate system. Volatility of components in vapor and liquid phases $f_{i,g}$ $f_{i,l}$, and a method for calculating their equilibrium is determined by the equation of state

$$p = RT\left[\frac{1}{V-b} - \frac{a}{V(V+c)}\right], \quad (7)$$

Here $V, L$ are the molar fraction of the gas and liquid phases. In the equation of state, $b$ and $c$ are constant coefficients for a given pure substance; $a$ is a temperature-dependent coefficient $(a = a_b\varphi(T))$ , $a_b$is a constant, $R$ is the universal gas constant, $\varphi$ is a function that depends on temperature and is equal to unity at the critical temperature.

Possibilities of extraction of liquid hydrocarbon reserves (retrograde condensate) lost in the formation by sequential injection of ethane and separated gas into the gas condensate layer at the final stage of development (in the pressure range below the maximum condensing pressure) were investigated. Technological indicators of the considered process are forecasted on the example of block V of horizon VII of Bulla-sea gas condensate field. As the separated gas is injected into the formation, the saturation and density of the liquid phase increase. The separated gas is enriched with ethane gas as it enters the formation, and the saturation of the liquid phase of the formation increases. Although some of the ethane remains in the gas phase, its bulk mass increases the volume of the liquid phase, and its hydrodynamic mobility occurs as a result of the saturation of the porous space with a sufficiently liquid phase. As a result, the amount of high molecular weight components in the production of production wells increases. As a result, the productivity of the formation due to condensate increases. After the formation of 10-20% of the residual reserves of ethane in the formation, the increase in condensate production compared to the depletion regime of the separation gas with the separation gas is about 7.7-10.8%, respectively.

In the second case, the issue of compressing retrograde condensate in a depleted reservoir was studied by adding gas to water at an optimal volume ratio. It is assumed that production and shock wells are operating in the reservoir. In the injection well, the amount of the water-gas mixture injected into the depleting formation is set, and in the production well, the yield of the product obtained in all three phases is determined. According to the general state of the reservoir, it is required to determine the technical and technological indicators of processing in the compression process mode.

The isothermal flow of a three-phase mixture of components $N$ in a porous medium is described by the following system of differential equations, obtained from a joint combination of the continuity equation for each component of the three phases, the generalized Darcy law, and the conditions of local thermodynamic equilibrium of the phases:

$$\nabla\left[k\left(\frac{f_w(s_w)}{\mu_w(p)}c_w^i\rho_w\nabla p_w+\frac{f_l(s_l)}{\mu_l(p)}\rho_l c_l^i\nabla p_l+\frac{f_g(s_g)}{\mu_g(p)}\rho_g c_g^i\nabla p_g\right)\right]=$$

$$=\frac{\partial}{\partial t}\left[m\left(\rho c^i\right)\right]+\sum_{\nu=1}^{n}Q_\nu^i\,(t)\delta(x-x_\nu,y-y_\nu)$$

$$i=1,2,3,\ldots,N\;\;(x,y)\in D,\;\;t\in(0,T),\quad(8)$$

$$\sum_{i=1}^{N}c_w^i=\sum_{i=1}^{N}c_l^i=\sum_{i=1}^{N}c_g^i=1,\qquad\sum_{i=1}^{N}c^i=1,$$

$$i=1,2,3,\ldots,N\;(x,y)\in D,\;\;t\in(0,T)\qquad(9)$$

Where $\rho$, $\rho_w$, $\rho_l$, $\rho_g$ - are the densities of the mixture and water, liquid (condensate), gas phase, respectively; $c^i, c_w^i$ , $c_l^i$, $c_g^i$- the proportion of the $i$-th component in the mixture, water, liquid (condensate) and gas phases, respectively; $m$- porosity; $k$- absolute permeability; $s_w$, $s_l$, $s_g$- water, liquid (condensate), gas-phase saturation, respectively; $f_w(s_w)$, $f_l(s_l)$, $f_g(s_g)$ – relative phase permeability of water, liquid (condensate), gas phase, respectively; $\mu_w(p), \mu_l(p), \mu_g(p)$ – viscosity of water, liquid (condensate), gas phase, respectively; $p_w$, $p_l$, $p_g$- pressure of water, liquid (condensate), gas phase, respectively; $\mu_l(p)$ – mass density of the $i-$ th component (flow rate per unit height), $n$ – number of wells; $\delta(\cdot)$ – Dirac delta function; $x_v$ and $y_v$; and coordinates along the abscissa and ordinate axes, respectively; $\nabla$ is the Hamilton operator; $D$- filtration area; time of processing; $t$ -time.

The connection between the phase pressures at the hydrocarbon gas-liquid and water-gas phase boundary is taken into account by capillary pressure, which expresses the action of capillary forces.

$$p_l = p_g - p_{clg} \quad p_w = p_g - p_{cwg}, \tag{10}$$

Here $p_{clg}$, $p_{cwg}$ – capillary pressure at liquid-gas and gas-water interfaces.

The system of equations (8)-(10) corresponding to the problem under consideration is supplemented with initial and boundary conditions

$$p_g(x,y,t)\Big|_{t=0} = p_{g0}(x,y), c^i(x,y,t)\Big|_{t=0} = c_0^i(x,y),$$
$$(0 \le x \le l_x; 0 \le y \le l_y), \tag{11}$$

$$\frac{\partial p_g}{\partial x}|x = 0, l_x = 0, 0 \le y \le l_y, \frac{\partial p_g}{\partial y}|y = 0, \quad l_y = 0,$$
$$0 \le x \le l_x. \tag{12}$$

Here, $l_x$ and $l_y$ the length and width of the layer, respectively.

The properties (density and viscosity) of the gas, liquid and water phases are determined from the solution of the following systems of equations

$$\begin{cases} f_g^i - f_l^i = 0, i = \overline{1, N} \\ f_g^i - f_w^i = 0, i = \overline{1, N} \\ c_l^i F_l + c_g^i F_g + c_w^i F_w - c^i = 0, i = \overline{1, N} \\ F_l + F_g + F_w = 1 \end{cases}, \tag{13}$$

Here in system (13) the first $(2N)$ number of equations expresses the condition of thermodynamic equilibrium of the volatile components of the gas-liquid and gas-water phases, and the other $(N+1)$ number of equations expresses the balance equations of the gas-liquid-water system.

According to the initial data of pressure $p_{г}$, temperature $T$ and the component composition of the mixture $c^i\left(i=\overline{1,N}\right)$, it is possible to determine the mole fraction of the liquid, gas and water phases $F_l$, $F_g$, $F_w$and the composition of the gas, liquid and water phases $c_g^i$, $c_l^i$, $c_w^i$ $\left(i=\overline{1,N}\right)$ into which the initial mixture is divided under given thermobaric conditions from system (13). In this case, the volatilities of the components $f_{i,g}$, $f_{i,l}$, $f_{i,w}$ in the gas, liquid (condensate) and water phases are determined by the equation of state (7) based on the known thermodynamic equilibrium relations. To solve the system of equations (13), the three-phase distribution coefficient of the $i$-th component is chosen in the following form:

$$k_i^{(1)}=\frac{c_g^i}{c_l^i}\ ,\ k_i^{(2)}=\frac{c_g^i}{c_w^i}, \tag{14}$$

From (14) it is obtained $c_g^i=k_i^{(1)};\ c_w^i=\frac{c_l^i k_i^{(1)}}{k_i^{(2)}}$.

Taking $F_g=1-F_l-F_w$, the distribution equation of the interfacial component of the mixture can be determined as

$$c_l^i F_l+c_l^i k_i^{(1)}(1-F_l-F_w)+c_w^i\frac{k_i^{(1)}}{k_i^{(2)}}F_w=c^i, \tag{15}$$

From here it is determined

$$c_l^i=\frac{c^i}{F_l(1-k_i^{(1)})+F_w(\frac{k_i^{(1)}}{k_i^{(2)}}-k_i^{(1)})+k_i^{(1)}}, \tag{16}$$

From (15)-(16) $c_w^i$, $c_g^i$ is defined as

$$c_w^i=\frac{c^i k_i^{(1)}}{k_i^{(2)}\left[F_l(1-k_i^{(1)})+F_l(\frac{k_i^{(1)}}{k_i^{(2)}}-k_i^{(1)})+k_i^{(1)}\right]}, \tag{17}$$

$$c_g^i = \frac{c^i k_i^{(1)}}{\left[F_l(1-k_i^{(1)})+F_w(\frac{k_i^{(1)}}{k_i^{(2)}}-k_i^{(1)})+k_i^{(1)}\right]}, \quad (18)$$

Equations (16)-(18) are the phase concentration equations of a three-phase system. (9) closed dependences and equations (16)-(18) make it possible to determine the mole fraction of phases and its composition at the values of the initial composition $c^i$, $k_i^{(1)}$and $k_i^{(2)}$ at the distribution coefficients of this mixture. In this case, the mole fractions of the phases are determined from the following equations:

$$\eta_1 = \sum_{i=1}^{N} \frac{c^i(1-k_i^{(1)})}{\left[F_l(1-k_i^{(1)})+F_w(\frac{k_i^{(1)}}{k_i^{(2)}}-k_i^{(1)})+k_i^{(1)}\right]} = 0, \quad (19)$$

$$\eta_2 = \sum_{i=1}^{N} \frac{c^i \frac{k_i^{(1)}}{k_i^{(2)}}}{\left[F_l(1-k_i^{(1)})+F_w(\frac{k_i^{(1)}}{k_i^{(2)}}-k_i^{(1)})+k_i^{(1)}\right]} - 1 = 0. \quad (20)$$

Equations (19)-(20) are non-linear with respect to the desired $\Delta F_l$ and $F_w$ molar amounts of phases. To solve a system of equations, it is necessary to linearize the equations included in it, and divide its functions $\eta_1$ and $\eta_2$ into Taylor series, when dividing with respect to $F_l$ and $\Delta F_w$ and be satisfied with the choice of linear limits. Then it is obtained

$$\begin{cases} \frac{\partial\eta_1}{\partial F_l}\Delta F_l + \frac{\partial\eta_1}{\partial F_w}\Delta F_w + \eta_1(F_l, F_w) = 0 \\ \frac{\partial\eta_2}{\partial F_l}\Delta F_l + \frac{\partial\eta_2}{\partial F_w}\Delta F_w + \eta_2(F_l, F_w) = 0 \end{cases}, \quad (21)$$

As a result of determining the roots of system (21), system (19)-(20) is solved by the method of successive approximations until the inequalities $|\eta_1| \le \varepsilon$, $|\eta_2| \le \varepsilon$ are satisfied, by recurrent relations $F_l^{j+1} = F_l^j + \Delta F_l$, $F_w^{j+1} = F_w^j + \Delta F_w$, their values $F_l, F_w$ are specified. Here $\varepsilon$ denotes the given accuracy of the solution to system (19)–(20).

The calculation method allows modeling the parameters characterizing the physical properties of the gas, liquid and water phases included in the system (8) - (12), depending on the current pressure, composition and temperature.

Calculations of technological parameters of the process of water-gas interaction were carried out on the V block sample of the VII horizon of the Bulla-Sea gas condensate field in two versions. The amount of water-gas mixture injected into the formation is given in the injection well and initially the formation pressure is increased from 12 MPa to 16 MPa by adding a certain amount of high-pressure gas to the water (in this case the volume of water-gas mixture injected into the reservoir 2:1), and then the compression of the gas condensate system with the water-gas mixture is considered to be constant (in this case, the volume of the water-gas mixture injected into the reservoir is equal to the volume of fluids extracted from the formation). In production wells, the production of the product is determined for each of the three phases. According to the general condition of the formation, the technological parameters of development in the compression process mode are forecasted on the example of block V of the VII horizon of the Bulla-Sea gas condensate field.

A comparison of the effects of water and water-gas mixture on the retrograde condensate settling in the horizon block shows that in the second case (under the influence of the addition of the gas phase to water), it is possible to increase the production of retrograde condensate by 10-14% (compared to conventional injection) and cleaner leaching of retrograde condensate under the influence of a water-gas mixture compared to conventional injection.

Also, as a result of the redistribution of retrograde condensate deposited in a gas condensate reservoir operating in depletion mode, along the height due to the action of capillary and gravitational forces, the formation of a man-made condensate reservoir at the gas-water boundary, and the solution of the possibility of producing retrograde condensate when drilling a horizontal well into it was investigated.

It is assumed that production wells located in any part of the gas condensate reservoir operate it in the depletion mode. The outer boundary of the formation is considered impermeable and the volume of the gas condensate system produced by production wells is set. It is required to evaluate the technological indicators of retrograde condensate production by a horizontal well drilled into a technogenic condensate stream formed at the gas-water boundary.

Determination of the technological parameters of the considered process was studied on the basis of a three-phase hydrodynamic model obtained on the basis of a joint combination of the continuity equation, the flow law, the equation of state of the phases and the equation of saturation between the phases and maintaining the state of local thermodynamic equilibrium of the phases.

Initially, during the operation of a horizontal gas condensate reservoir in the form of a parallelepiped with a five-spot production well, the average molar composition of the gas condensate system (mol. quantity,%) is methane 88.59, ethane 4.11, propane 1.47, butane 0.77, $C_{5+}$-4, 86, carbon dioxide is 0.2, and the values of the parameters characterizing the reservoir, as well as due to changes in the properties of its fluids in terms of molar composition, the nature of the distribution of reservoir pressure and phases, determine the height, the time of formation of technogenic condensate and the interval of occurrence at the total height of its gas content.

In the second case, the irrigation stimulation method was chosen for the production of retrograde condensate by a horizontal well drilled into the technogenic condensate reservoir, and implemented by production wells operating the irrigation reservoir. At the same time, according to the amount of injected water, the injection pressure was selected in such a way that it did not exceed the hydrostatic pressure in the wells.

The effective duration of irrigation is determined by the 98% water cut of the horizontal well production. In this case, two cases of the irrigation process were considered, differing in the choice of perforation options in the wells. In the first case, the wells open the productive height of the reservoir from the upper part, and in the second case, from the lower part, and after the condensate exits, a horizontal well is put into operation. Based on the generalization of the obtained results of technological indicators of the operation process, it was established that: during the operation of a gas condensate reservoir in the pumping mode, the formation of techno-condensate waters at the water-gas boundary is the result of the segregation process; increasing the amount of bound water in the formation increases the rate at which the segregation process occurs. The absence of associated water in the reservoir means that the process of segregation of the liquid hydrocarbon phase practically does not occur; the greatest effect in increasing the condensate flow rate of a horizontal well drilled into a man-made condensate field formed in a depleted reservoir is achieved by pumping a water-gas mixture from the ceiling (upper part) of the reservoir.

Thus, after the creation of a certain volume of ethane gas into the gas condensate reservoir at the last stage of the depletion regime, the physical essence of interaction with the separation gas is the removal of retrograde reserves of hydrocarbon condensate by providing a significant shift in the phase balance in the two-phase system towards the liquid phase. The purpose of adding gas components to the pumped water is to increase the degree of compression of the gas condensate mixture. The water-gas reaction can be carried out at a constant pressure corresponding to the minimum values of viscosity and density of the condensate settled in the reservoir, which facilitates the process of retrograde washing of the condensate. It is also considered expedient to operate the gas condensate reservoir in the reservoir energy depletion mode until the maximum condensation pressure is reached. Then the transition to the water-gas effect is effective. In this case, the retrograde condensate deposited in the reservoir is completely compressed into production wells. At the same time, as a result of the redistribution of retrograde condensate deposited in a gas condensate reservoir operating in depletion mode along the height due to the action of capillary and gravitational forces, it can be considered an effective way to extract the liquid phase. with a horizontal well drilled into a man-made condensate reservoir formed at the border of gas and water, and with this approach, traditional methods of secondary impact have their advantages.

**In the third chapter,** the possibility of retrograde condensate evaporation in the periodic treatment of the well bottom zone of gas condensate wells with hot liquid hydrocarbons, the assessment of the efficiency of combined treatment with liquid hydrocarbons and gas were resolved.

The conducted studies show that the collection of retrograde condensate in the near-wellbore zone has recently attracted great interest, as it is associated with well productivity. The near-wellbore zone is a special zone of the reservoir and not only determines the well flow rate, but also has a great influence on the production of gas and condensate from the reservoir. A few meters around the well there is resistance to seepage of fluids to the bottom of the well. Therefore, a slight deterioration (deterioration) in the filtering properties of the reservoir significantly reduces the productivity of wells in this zone.

At present, it is of great importance to determine the factors that lead to a decrease in well productivity and to study ways to eliminate them.

A decrease in the volume of the liquid phase collected in the gas condensate reservoir and its bottomhole zone when operating in the depletion mode requires a change in the temperature regime in this zone, or rather, its increase. A certain degree of temperature increase near the bottomhole zone of a gas condensate well can stimulate the evaporation of the liquid phase and at the same time somewhat improve the filtration characteristics of the bottomhole zone of the well. From this point of view, it is possible to increase the productivity of gas condensate wells by reducing the volume of the liquid phase collected in them and improving the operating mode due to the effect of heat on the bottomhole zones.

On the basis of the non-isothermal multicomponent model of filtration, the process of development of the well bottom zones of the wells of the V block of the VII horizon of the Bulla-Sea gas condensate field with hot liquid hydrocarbons was studied. During the development, the cases of injection of liquid hydrocarbons into the well at a higher temperature compared to the temperature of the formation mixture were investigated. The injection of hot propane and then hot dry gas as a mixture of liquid hydrocarbons, as well as the injection of liquid hydrocarbons with hot propane-butane fraction and then dry gas were considered.

In the initial case, liquid propane and high-temperature methane gas during treatment evaporate the retrograde liquid collected in the bottomhole zone and simultaneously compress some of it into the reservoir, which sharply reduces the saturation cost of the liquid phase. Propane aratha is formed near the bottom of the well. After the well is started, liquid slag increases in volume and comes closer to the bottomhole zone of a certain reservoir and remains inactive for a long time. In the first moments of operation, well productivity increases by 100-150%, and production remains stable for a long time. As a result of the re-accumulation of the liquid phase in the bottomhole zone, well productivity is gradually decreasing. The downward trend in well productivity is weak compared to the favorable results of traditional compressed propane gas treatment. Compared to pre-development wells, there is a clear tendency for production to remain high for some time.

In the second case, the propane-butane fractions injected into the wells mix with the liquid column collected in the bottomhole zone and set it in motion. More precisely, hot liquid and gas fractions entering the reservoir provide intensive evaporation of light and relatively medium components of retrograde condensate and compression of relatively heavy components. As a result, an accumulation zone of a relatively small volume is formed compared to the initial volume of the liquid phase collected in the pores. After treatment, the liquid phase, suitable for putting wells into operation, reappears in the bottomhole zone. The sedimentation process mainly occurs near the wellbore. In the first moments of operation, well productivity increases by 80-130%, and production remains stable for a long time.

The treatment of the wells around the wells with hot liquid hydrocarbons allows to reduce the volume of the injected reagent several times in order to obtain the same productivity as the results of isothermal treatment.

Also, while maintaining the volume constant, the procedure for increasing the efficiency of processing dry gas, dry gas, a certain amount of nitrogen and carbon dioxide, as well as propane-butane fractional composition with dry gas - dry gas+nitrogen, dry gas, dry gas +carbon dioxide, propane-butane fractionated liquid mixture +dry gas - sequence determined.

Thus, the possibility of intensifying liquid condensate production indicators in the process of treating the bottomhole zone of gas condensate wells with hot light liquid hydrocarbons is substantiated and the procedure for increasing the current efficiency of gas condensate well treatment is determined.

**The fourth chapter** considers the problem of preventing gas from the gas condensate cap from entering the oil stream by forming a screen at the level of the oil-gas interface in the oil and gas condensate reservoir, as well as solving the problems of processing the oil stream by returning gas from the product obtained from the gas condensate cap to the oil stream.

Oil production from oil and gas condensate fields is characterized by rather low rates compared to conventional oil fields. If in oil fields oil recovery is 30%, then in oil and gas condensate fields it is 10-15%. The sequence of exploitation of gas and oil reserves is considered one of the important factors in the development of oil and gas condensate fields. Initially, the most effective is the simultaneous production of oil and gas, so that the oil reserves or the oil and gas boundary do not shift. Otherwise, there may be a loss of oil reserves. If initially the development of oil in a homogeneous high-permeability formation is carried out by using the elastic energy of the gas cap reserves, then the value of the oil recovery factor is higher than a certain calculated one. However, in most cases, the flow of gas into the oil field leads to a sharp decrease in pressure in the gas cap, as a result of which an impulse is given to shift the oil field into a gas-bearing region and cause it to mix with the gaseous part. The pressure drop in the gas cap leads to the deposition of retrograde condensate in the reservoir. There are problems associated with the involvement of gas resources in the development.

When developing oil and gas condensate fields, it is considered expedient to organize the separation of the gas and oil parts into two different objects and develop them independently of each other.

From this point of view, the development of the oil potential of the gas condensate reservoir at the level of the oil and gas boundary with various compression agents (irrigation, polymer-water mixture, binder polymer, foam system, water-gas mixture, thermogas, etc.) is considered the issue of processing in accordance with the technological solution to prevent penetration. It is required to predict the oil production rate and other technological indicators of the field.

Mathematical modeling of the process, the following differential equations obtained from a combination of initial and boundary conditions for continuity and state equations for each component in all three phases (oil, water, gas) and generalized Darcy's law and local thermodynamic equilibrium relations of phases, pressure and phase saturation is described by:

$$\nabla\left[\left(\frac{khf_g\rho_g}{\mu_g M_g}l_g^i\nabla p_g+\frac{khf_o\rho_o}{\mu_o M_o}l_o^i\nabla p_o+\frac{khf_{\mathrm{w}}\rho_w}{\mu_w M_w}l_w^i\nabla p_w\right)\right]=$$

$$= \frac{\partial}{\partial t}\left[mh\left(\frac{\rho_g s_g}{M_g} l_g^i + \frac{\rho_o s_o}{M_o} l_o^i + \frac{\rho_w s_в}{M_w} l_w^i\right)\right] \pm$$

$$\pm \sum_{\nu=1}^{s} \left(Q_{g\nu}^i(t) + Q_{o\nu}^i(t) + Q_{w\nu}^i(t)\right) \delta(x - x_\nu)\delta(y - y_\nu),$$

$$i = \overline{1,3}\,,\ (x,y) \in D\,,\ t \in (0,T)\,, \tag{22}$$

$$div\left(khc\frac{f_w \rho_w}{\mu_w M_w} Dgradp_w\right) + \frac{\partial}{\partial t}\left[h(mcs_w + a)\frac{\rho_w}{M_w}\right] =$$

$$= div\left(h\frac{\rho_w}{s_w} Dgradc\right) +$$

$$+ \sum_{\nu=1}^{s} Q_{w\nu}^i(t)\delta(x - x_\nu, y - y_\nu), \tag{23}$$

$$p_g(x,y,t)|_{t=0} = p_{g0}(x,y),$$

$$s_g(x,y,t)|_{t=0} = s_{g0}(x,y), s_o(x,y,t)|_{t=0} = s_{o0}(x,y),$$

$$s_w(x,y,t)|_{t=0} = s_{w0}(x,y), c(x,y,t)|_{t=0} = c_w(x,y),$$

$$(x,y) \in D, \tag{24}$$

$$\left.\frac{\partial p_g(x,y,t)}{\partial n}\right|_{\Omega} = 0, \qquad \left.\frac{\partial c(x,y,t)}{\partial n}\right|_{\Omega} = 0, \qquad (x,y) \in \Omega,$$

$$t \in (0,T), \tag{25}$$

$$\sum_{i=1}^{3} l_g^i = \sum_{i=1}^{3} l_w^i = \sum_{i=1}^{3} l_o^i = 1,\ \ s_g + s_o + s_w = 1, \tag{26}$$

Here $l_w^i$, $l_o^i$, $l_g^i$- $i$-th component proportion in water, oil-$c$-water, and gas, respectively; $p_w$,$p_o$, $p_g$- pressure of water, oil, gas phase, respectively; $Q_{w\nu}^i(t)$, $Q_{o\nu}^i(t)$, $Q_{g\nu}^i(t)$- mass density for the $i$-th component, oil and gas (flow rate per unit height); $c$-volumetric concentration of the trapping agent in the aqueous phase; $a(s_w, c)$-amount of entrained agent per unit volume of the porous medium;
$s$ - number of wells; $M_g$, $M_o$ and $M_w$ are the average molecular.

The relationship between the phase pressures at the hydrocarbon gas-oil and oil-water phase boundary is taken into account by expression (10), which expresses the action of capillary forces.

In the system equations (22) - (26), the unknown quantities are the pressure $p_g(x, y, t)$ of the gas phase and the saturation of the mixture $s_g$ for gas, $s_o$ for oil and $s_w$ for water, and the concentration of the compressor $c$ in the water phase.

Properties of gas, oil and water phases (density and viscosity) are determined from the solution of the corresponding system of equations (13).

When creating a gas-oil boundary level screen with different compression agents, the values of the relative gas phase permeability for each approach are taken into account as the ratio of the gas phase permeability before and after the technological solution:

$$f_{rppg}\,(s, c) = \frac{f_g(s, c)}{k_{rr}}, \qquad (27)$$

$k_{rr}$ is the residual resistance coefficient and is determined experimentally; $f_g(s, c)$ - relative phase conductivity of the gas up to the technological solution variant; $f_{rppg}\,(s, c)$ - is the relative phase permeability of the gas after the technological solution.

Based on the proposed computational algorithm, in the example of the "Fasila" formation of a specific Bahar field with different compression agents at the level of the oil and gas border (pumping, polymer water mixture, binder polymer, foam system, water-gas mixture, thermogas, etc.) technological indicators of development by preventing the ingress of gas from the gas condensate cap into the oil mixture by forming a screen have been predicted in the example of the "Fasila" formation of Bahar field.

The formation was first developed in the natural formation mode, and then by injecting water to maintain the formation pressure. Processing in the natural formation mode took place with the gas mode and the contour water pressure (base variant). During development, 16.7%, 79.3% and 41.1% of the initial balance reserves for oil, gas and condensate were extracted from the field, respectively.

Compared to the base option, the artificial reduction of the phase permeability for gas in the local filtration zones during the entire development period under consideration slows down the expansion of the gas cones, resulting in stabilizing the gas factor, increasing oil production and ensuring field development efficiency. In the application of cross-linked polymer systems (binding polymer systems) and thermo-gas exposure, the oil recovery coefficient and the value of the water content of the product are considered quite reasonable.

Also, the issue of assessing the efficiency of oil refining development by returning the oil from the product extracted from the gas condensate cap of the oil and gas condensate layer to its oil mediumis also examined. The gas extracted from the gas cap is returned to the oil section after separation by means of injection wells drilled to the level of oil-water contacts. The dry gas pushes the oil from the oil tank to the gas cap, and at the same time enters the gas cap by evaporating the moving oil, and is extracted by production wells operating in the gas cap, and the process continues uninterrupted. The development indicators of the technological approach were forecasted on the example of a specific formation model and compared with the results of the option of processing the oil mixture with the depletion mode to assess its effectiveness. In the process of depletion, the oil recovery factor is characterized by an approximately low value. The mode of return of separation gas from the oil-water contact boundary to the oil well by injection wells provides a more than 2.6-fold increase in oil recovery coefficient compared to the depletion mode, while maintaining stable oil displacement and evaporation of oil moving in the pore space and capillary closed. In this case, due to the reduction of residual oil saturation, there is an increase in the compression ratio in the gas-washed zones, and stable oil is filtered into the production well before evaporating oil, and its share in total production is quite low.

The main share of the liquid hydrocarbon system in the production consists of components higher than $C_{5+}$.

In order to prevent local deformation of the gas-oil and water-oil contact in the development of the oil-bearing gas condensate layer and, consequently, global deformation of the entire oil contact, alternative methods of active impact on the reservoir, including gas from the gas condensate cap, return, as well as joint exploitation of oil, gas and water by a single-row NPC with injection of water into the oil tank, the water-oil section below the water-oil contact (direct method of gas and water injection); injection of dry gas from the roof of the formation to maintain the formation pressure at high values of the gas condensate factor and compression of oil from the gas condensate cap to the production wells at the expense of oil gas (method of injection of gas into the gas cap); maintenance of pressure below the initial level of the water-oil contact by injecting gas into the aquifer and water into the gas cap (reverse gas and water injection method); depletion of oil due to the active movement of heel water by injecting water into the aquifer (water injection into the aquifer); water injection into the gas cap; injection of water into the gas cap and then injection of gas into the lower part of the water-oil contact below the initial level (method of alternating injection of gas and water); and so on. The issue of assessing the effectiveness of increasing oil yield in the application of existing methods has been investigated on the example of a concrete oil-bearing gas condensate layer.

In depletion mode, a fairly low oil recovery factor is obtained. This is due to the fact that as a result of the entry of the gas field into the oil field, the current oil factor increases over time and the flow rate of wells decreases due to oil. The fact that the oil recovery factor is quite large compared to the depletion regime in the case of water impact on the aquifer is due to the difficulty of gas entry into production wells as a result of the gradual influx of oil from the oil cap into the reservoir gas cap. The increase in the thickness of the oil mixture under the influence of water on the gas cap provides a high increase in the oil recovery factor compared to the depletion regime. The high increase in the coefficient of oil recovery under the influence of gas on the gas cap and water on the aquifer is achieved by maintaining a fairly stable state of the oil mixture. In the anisotropic layer, the coefficient of oil recovery of the gas cap under the influence of water and gas on the aqueous part is quite high compared to other methods. In the isotropic layer, the value of the oil recovery factor under the influence of gas on the cap and water on the aquifer is higher than on other methods. The share of relative porosity volumes of gas and water injected into the reservoir also has a significant impact on the technological parameters of development. Reducing the volume of gas injected in the anisotropic formation provides an increase in the oil recovery factor compared to the results of a similar process in the isotropic formation. Reducing the share of the relative pore volume of the injected gas while maintaining the pressure in the anisotropic layer leads to a reduction in energy consumption and an increase in the efficiency of the process.

In general, the development of an oil-bearing gas condensate layer is more effective in terms of increasing oil production than other methods of injecting water into the gas cap and water into the aquifer. The water entering the aquifer and the water injected into the gas cap enter the oil mixture, which promotes three-phase filtration. As a result, the phase conductivity of the gas decreases sharply due to the residual water content formed in the oil mixture, and it is difficult for the gas to enter the gas cap. The vertical ascent of the new gas inlet from the aquifer is difficult, and as a result it is attracted to the horizontal. Due to the mobility of the gas in the oil field, it cannot enter the aquifer, which is injected into the gas cap, and a favorable regime of oil injection into production wells is formed.

The order of increase of the effectiveness of the impact methods in the isotropic layer - water injection into the gas cap; injection of water into the aquifer; injection of gas into the gas cap;

injection of water into the aquifer; alternate injection of gas and water; injection of water into the gas cap, gas injection into the aquifer; gas injection into the gas cap, water injection into the aquifer - in sequence, and in the anisotropic layer - gas injection into the gas cap, water injection into the aquifer; gas injection into the gas cap; water injection into the aquifer; gas and water injection; identified by the sequence of gas injection into the aquifer.

The issue of assessing the effectiveness of the development of oil-bearing gas condensate fields in the oil zone with the use of horizontal wells was investigated and a comparative analysis of the technological parameters of the depletion regime and oil-water displacement regime was conducted. It was found that the oil-to-water pumping regime provides a sharp increase in oil recovery ratio compared to the depletion regime and a long-term slow decline in production well debit for degassed oil, and profitable production. The advantage of the depletion regime in the early stages of development compared to the dynamics of the total oil production with water is identified. In the depletion mode of petroleum refining, the non-gaseous oil production option provides a substantial increase in oil recovery compared to other regime options (gas cap and oil mixing option, separate oil tank development option, etc.).

**In the fifth chapter**, the gas hydrodynamic issues of forecasting the development indicators of the system options for the development of gas dynamically connected multilayer gas condensate fields are solved.

In most cases, gas condensate deposits are multilayer. In many cases, if the fertile horizon consists of fertile layers separated by clay, it is considered appropriate to divide it into separate layers. Such deposits are operated jointly, separately, separately, by a network of wells. When implementing an integrated network of wells, each well simultaneously exploits two or more reservoirs. In addition, when using a network of wells, each layer is exploited with a well drilled in it. When exploiting multilayer fields with joint wells, the number of wells is reduced compared to the exploitation of individual wells.

Nevertheless, when the field is exploited by individual wells, the work of monitoring its development is simplified. Predicting field performance using joint wells becomes very difficult. There are also technical difficulties in carrying out repair and insulation work. It is considered impossible to determine in advance which of the options for operating multilayer gas condensate fields with a network of wells has a certain advantage. This requires multivariate technical and economic calculations, taking into account the mining and geological features of the deposit.

In this regard, in the first case, the issue of joint operation of a gas condensate field with a homogeneous two-layer connected and low-permeability arad with one well is considered. One of the reservoirs is operated with stable gas production by a separate network of wells. The layers are initially sealed and compacted. It is required to predict well and reservoir pressures in each reservoir, as well as the dynamics of changes in the amount of gas and condensate flowing from one reservoir to another through condensate outbursts and low-permeability liquid.

Prediction of efficiency indicators is carried out by solving a two-phase two-component system of equations of a gas condensate system that satisfies the initial and boundary conditions. In this case, the amount of gas condensate mixture flowing from one reservoir to another is determined by the pressure difference between the reservoirs.

The values of the parameters expressing the physical properties of the gas condensate system, corresponding to changes in pressure, temperature and composition of the mixture included in the calculation model, are determined by the results of solving the system of equations describing depletion in the mode of the differential condensation process, and the current pVT data are taken into account during processing.

In the initial case, the results of the performance indicators of a two-layer gas condensate field with a well of poor permeability were analyzed, taking into account the flow between the layers, and it was determined that:

When the second layer (lower layer) is mined by a production well, a pressure drop occurs in the first layer due to mass transfer between the layers corresponding to the pressure drop, and, as a result, the rate of condensation from the gas phase in the first layer gradually increases. In the initial period of treatment, the accumulation of the liquid phase (deposition of retrograde condensate) in the first layer is observed in a fairly small volume, while in the second layer this process proceeds more intensively. At the final stage of processing, the process of deposition of retrograde tonnensat in the first layer proceeds more intensively, and in the second layer the opposite process, i.e., the rate of the process of condensate deposition, slows down.

The volume of the gas phase coming from the first reservoir to the second increases, and it evaporates some of the retrograde condensate deposited in the second reservoir and ensures its movement to the production well. As a result, the absorption rate of the gas condensate factor in the second layer weakens, while in the first layer, the growth rate of the latter somewhat increases. The production of the second layer due to condensate increases at a high rate in the initial period of treatment, and for a certain period of time in subsequent periods of treatment, the rate of its decline sharply decreases, and in the subsequent period of treatment, the rate of decline becomes very weak and takes on a stable form.

The amount of gas and condensate flowing from the first reservoir to the second one decreases as the aragat permeability decreases. As the value of aragat rises, the condensate yield of the second layer increases, and at the same time, more condensate occurs in the first and second layers during processing. Also, with a decrease in the value of alcohol, there is a sharper decrease in the valuesof the condensate factor in the first layer and a sharper increase in the second layer. This is explained by the fact that, due to the permeability, the pressure drop in the first layer is less, and in the second layer it is greater. Also, the pressure drop in the first and second layers increases as the aragat permeability decreases.

In the second case, during the joint operation of a layered reservoir with a well, the influence of the dynamic condensation process on the accumulation of retrograde condensate in the bottomhole zone, as well as on the deterioration of the reservoir properties of the bottomhole zone, was revealed. assessed, and the collection of liquid condensate in the near-wellbore zone, the increase in resistance forces during the infiltration of the gas phase into a single network of wells, the presence of gas in the well production and determined that this caused a sharp decrease in production due to condensate.

Also, during the operation of a two-layer field with a single-grid well, a method was developed for solving the inverse problem of gas condensate mixture filtration in reservoirs based on a variational approach and the possibility of identifying percolation ones - the capacitance parameters of each deformed layer were determined based on the actual data of the layer.

Thus, the determination of indicators performance in accordance with the actual conditions of the joint operation of a gas condensate field with a homogeneous two-layer connected and low-permeability reservoir with the same well (by changing the phase state) and the dynamics of changes in the total production of the well, as well as the production of each reservoir in terms of gas and condensate depending on the period of operation. Also, during the exploitation of a two-layer heterogeneous field with a single-grid well, a method was developed for solving the inverse problem of gas condensate mixture filtration in reservoirs based on a variational approach, and the parameters of the filtration capacity of each deformed layer were identified.

**In the sixth chapter,** taking into account the dynamic relationship of the formation-well system, the direct and inverse problems of modeling the process of depletion of gas condensate deposits on the basis of equations of motion of gas-liquid mixture in the formation and wellbore were considered and their solutions were implemented.

Since deep-seated gas condensate deposits are characterized by high thermobaric conditions (high pressure and temperature), operations to measure bottom hole parameters are associated with great difficulties. Therefore, the theoretical definition of bottomhole pressure and other technological indicators of development based on the parameters of wellhead operation in the development of gas condensate fields seems to be of practical importance for strict observance of the technical safety of operating at abnormally high pressures. fields in the development process and exclude operations that are supposed to be carried out to measure the values of the parameters of the wellbore.

The theoretical solution to this problem is provided by taking into account the dynamic relationship of the reservoir-well system. To do this, it is necessary to jointly solve a system of equations describing the flow of the gas condensate mixture in the reservoir and wellbore, taking into account the phase state of the gas condensate system.

In this regard the straightforward problem of modeling the development process of the deep gas condensate layer according to the wellhead data was realized in the following option: A finite homogeneous anisotropic layer bounded by two impermeable surfaces of height $H$ and radius $R$ opens an incomplete well with an $L = H_2 - H_1$ filter and operates with a $Q_0^w(r_c, t)$ flow rate (Fig. 1). $p_0$, $s_0$, are taken according to the initial pressure and condensate saturation in the layer before the start of processing. Determination of wellhead and formation pressure, as well as other technological parameters of development is required on the basis of wellhead pressure information.

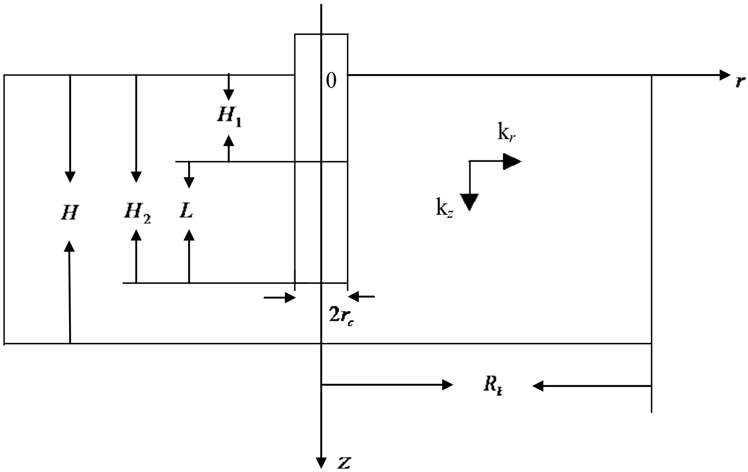


Figure 1. Schematic diagram of a L filter well in a homogeneous anisotropic layer

The mathematical model of the problem under consideration includes the following system of equations:

1. System of equations of filtration of gas-condensate mixture in the layer.

2. System of equations of flow of gas-condensate mixture in the wellbore.

3. Equations of the phase state of the gas-condensate mixture in the reservoir and wellbore.

System equations of gas condensate system filtration is solved

$$\frac{1}{r}\frac{\partial}{\partial r}\{rk_r V_g(r,z,t,s_k,p)\} + \frac{\partial}{\partial z}\{k_z V_g(r,z,t,s_k,p)\} =$$
$$= \frac{\partial}{\partial t}\{m(A(r,z,t,p) + s_k B(r,z,t,p))\}, (r,z) \in D,$$
$$t \in (0,T), \qquad (28)$$
$$\frac{1}{r}\frac{\partial}{\partial r}\{rk_r V_k(r,z,t,s_k,p)\} + \frac{\partial}{\partial z}\{k_z V_k(r,z,t,s_k,p)\} =$$
$$= \frac{\partial}{\partial t}\{m\big(C(r,z,t,p) + s_k D(r,z,t,p)\big)\}, (r,z) \in D,$$

$$t \in (0,T), \tag{29}$$

within the following initial and boundary conditions

$$p(r,z,t)\big|_{t=0} = p_0(r,z), s_k(r,z,t)\big|_{t=0} = $$
$$= s_{k0}(r,z), (r,z) \in D, \tag{30}$$

$$k_r\left(V_g(r,z,t,s_k,p) + V_k(r,z,t,s_k,p)\right)\big|_{r=R_k} = 0,$$
$$k_z\left(V_g(r,z,t,s_k,p) + V_k(r,z,t,s_k,p)\right)\big|_{z=0;H} = 0,$$
$$t \in (0,T), \tag{31}$$

$$2\pi r_c \int_{H_1}^{H_2} k_r\left(V_g(r,z,t,s_k,p) + V_k(r,z,t,s_k,p)\right)\big|_{r=r_c} dz =$$
$$= \begin{cases} Q_0^W(r_c,t), z \in L \\ 0, \qquad\quad z \notin L \end{cases}, t \in \ (0,T) \tag{32}$$

Here

$$V_g(r,z,t,s_k,p) = \left(\frac{F_q(s_g)p\beta[1 - c(\rho)\bar{\gamma}(p)]}{\mu_g(p)z(p)p_{at}} + \frac{F_k(s_k)S_k(p)}{\mu_k(p)a_k(p)}\right) \cdot$$
$$\cdot \left(\frac{\partial p}{\partial r} - \gamma_g \frac{\partial H}{\partial r}\right),$$

$$V_k(r,z,t,s_k,p) = \left(\frac{F_g(s_g)p\beta c(\rho)}{\mu_g(p)z(p)p_{at}} + \frac{F_k(s_k)}{\mu_k(p)a_k(p)}\right) \cdot \left(\frac{\partial p}{\partial r} - \gamma_k \frac{\partial H}{\partial r}\right),$$

$p(r,z,t)$ - pressure; $s(r,z,t)$- condensate saturation; $F_g(s)$ and $F_k(s)$- are the theoretical phase conductivities of the gas and liquid phases, respectively; $c(\rho)$- is the amount of condensate in the gas phase; $\bar{\gamma}(p)$ - is the ratio of the volume and weight of condensate in the liquid and gas phases under normal conditions; $S_k(p)$- is the amount of gas soluble in the liquid; $a_k(p)$- is the volume coefficient of the liquid phase; $m$-porosity coefficient of the rock; $t$- time; $p_{at}$-atmospheric pressure; $\beta$ and $z(p)$ - temperature correction and gas phase compression ratios, respectively; $\mu_g(p)$and $\mu_k(p)$ - viscosities of gas and liquid phases, respectively; $D$ - filtration area; $t$ - time;
$T$ - development period; $H$ - the upper boundary relative to the $z$-axis of the layer; $r_c$, $R_k$-Relevant drainage radius of the well and

formation; $k_r, k_z$ $r$ - and $z$ conduction coefficients in the direction of the axes; $Q_0^w(r_c,t)$ - is an unknown production from the formation to the well, and the wellhead is determined by the pressure under the condition of the dynamic connection of the formation-well system.

System equations of flow in the wellbore of a gas condensate system

$$\frac{\partial^2 u_g}{\partial t^2} + \frac{Q_0^w(r_c,t)}{\varphi_g f}\frac{\partial^2 u_g}{\partial t \partial z} = \frac{\delta(z-0)}{\rho_q}p_c(t) - \frac{\delta(z-l)}{\rho_q}p_{ga.}(t) +$$

$$+a_g^2\frac{\partial^2 u_g}{\partial z^2} + \frac{4}{3}\nu_g\frac{\partial^3 u_g}{\partial t \partial z^2} - \left(2h_g + \frac{K}{\rho_g}\right)\frac{\partial u_g}{\partial t} + \frac{K}{\rho_g}\frac{\varphi_l}{\varphi_g}\frac{\partial u_l}{\partial t}, \qquad (33)$$

$$\frac{\partial^2 u_l}{\partial t^2} + \frac{Q_0^w(r_c,t)}{\varphi_l f}\frac{\partial^2 u_l}{\partial t \partial z} = \frac{\delta(z-0)}{\rho_l}p_c(t) - \frac{\delta(z-l)}{\rho_g}p_{ga.}(t) +$$

$$+a_l^2\frac{\partial^2 u_l}{\partial z^2} + \frac{4}{3}\nu_l\frac{\partial^3 u_l}{\partial t \partial z^2} - \left(2h_l + \frac{K}{\rho_l}\right)\frac{\partial u_l}{\partial t} + \frac{K}{\rho_l}\frac{\varphi_g}{\varphi_l}\frac{\partial u_g}{\partial t}, \qquad (34)$$

within the following initial and boundary conditions

$$\left.\frac{\partial u_g}{\partial t}\right|_{t=0} = \left.\frac{\partial u_l}{\partial t}\right|_{t=0} = 0,$$

$$u_g\,|_{\,t=0} = u_l\,|_{\,t=0} = 0, \qquad (35)$$

$$\left.\frac{\partial u_g}{\partial z}\right|_{z=l} = \left.\frac{\partial u_l}{\partial z}\right|_{z=l} = 0,$$

$$u_g\,|_{\,z=0} = u_l\,|_{\,z=0} = 0, \qquad (36)$$

are solved. Where $u_g$ and $u_l$ is the displacement deformation of the gas and liquid phases at any cross section of the wellbore, respectively; $a_g$, $a_l$- speed of sound wave propagation in gas and liquid phases, respectively; $\rho_g$, $\rho_l$ - density of gas and liquid phases in the horizontal pipe, respectively; $p_c(t), p_{wh.}(t)$, - wellbore and wellhead pressure; $f$ - cross-sectional area of the horizontal pipe; $\varphi_g$, $\varphi_l$ - volume concentration of gas and liquid phases in the mixture in the horizontal tube; $\nu_g$, $\nu_l$ - kinematic viscosity of gas and liquid phases in the horizontal tube; $K$- coefficients of interaction between gas and liquid phases in a horizontal pipe; $l$- length of the wellbore; $h_g$, $h_l$ -resistance coefficient of gas and liquid phases.

To solve the system of equations (28)-(32) and (33)-(36), they are supplemented (closed) with the equations of the phase state of the gas condensate system. Equations of the phase state. Here it is solved together with the equation of state, and as a result the parameters characterizing the physical properties of the mixture are determined, $z_i$, $i = \overline{1, N}$ the density of the molar composition and molar fraction are identified when each phase is in equilibrium due to changes in pressure, temperature and component composition of the mixture.

To solve the problems (28) - (32) and (33) - (36) the calculation scheme "indistinct for pressure and obvious for condensate saturation and fluid displacement" is used.

The algorithm for calculating the forecast of deep gas condensate field development in depletion mode includes the following calculations: In the first step $Q_0^w(r_c, t)$, the gas condensate mixture entering the well is assumed to be equal to the gas-liquid mixture produced at the wellhead. Then the value of $p_c(t)$ is determined from equation (32) according to the initial pressure $p_0$ and $s_{k0}$ condensate saturation data and the known value $Q_0^w(r_c, t)$ , as well as the value of the parameters characterizing the physical properties of the gas condensate mixture determined from systems (6), (7).Then solving the system equations (28) - (32) and (33) - (36) the numerical values $p$, $s_k$, $u_g$, and $u_l$ will be found for the new time step. The value of $Q_0^w$ in the next moment

$$Q_0^w(r_c, t) = f\left(\varphi_g \frac{\partial u_g(0,t)}{\partial t} + \varphi_l \frac{\partial u_l(0,t)}{\partial t}\right)$$

at each instant, and in equation (32), the appropriate $p_c(t)$ is determined taking into account the parameters characterizing the physical properties of the gas condensate mixture at that instant, and the calculation procedure is repeated.

Based on the values of the parameters characterizing the physical properties of the phases of the gas condensate mixture according to the current values of formation pressure and temperature, the dependence of the change in pressure, gas and condensate flow rate on the well, contour and wellhead was identified and their results were compared. Sharp differences in wellhead and contour pressures, condensate and gas flow rates were identified.

At the same time, according to the degree of opening of the anisotropic reservoir, according to wellhead data, the regularity of accumulation of retrograde condensate along the height of the reservoir in the bottomhole zone of incomplete wells was determined and the possibility of choosing suitable measures to improve the efficiency of wells by correctly determining the location of the reservoir opening was confirmed.

There are certain difficulties in obtaining information about the porosity and reservoir properties of the reservoir system, including core measurement methods, as well as the implementation of complex measures for geophysical and hydrodynamic studies of wells, etc. In the normal operation of hydrocarbon reservoirs, this leads to numerous problems in regulation and management.

To eliminate the lack of information and to carry out the correct setting of the workflow Finding unknown layer parameters (filtration capacity parameters) from the solution of the inverse problem of the filtration theory with the application of the methods of the theory of optimal control seems important from a practical point of view.

According to the wellhead data, the method of parametric identification using the method of variance was developed and implemented in the example of a concrete formation model, taking into account the dynamic relationship of the formation-well system to determine the filtration-capacity properties of the deformed layer in the filtration of gas condensate mixture. Implementation of the determination method allows to purposefully and effectively specify hydrodynamic models of leakage processes in the gas condensate layer in the conditions of incompleteness and inaccuracy of primary geological and mining data provides appropriate adjustment.

From this point of view, a method for parametric identification of the deformation-capacitive properties of a deformation formation was developed when filtering a gas condensate mixture according to wellhead data by applying a variational method, taking into account the dynamic dependence of the reservoir-well, and implemented on the example of a specific reservoir model. At this time, the considered direct problem (reservoir-well system equations) is solved using the initial values of productivity and filtration parameters by the finite difference method. As a result, pressure is detected at various points in the reservoir as well as in the well. The time dependence of the difference between the actual and calculated pressure values in the well is determined. Based on the dependence between the pressures in the well, the conjugate boundary value problem is constructed and the conjugate boundary value problem is solved. The gradient is determined at different points of the layer by the capacitive and filtering parameters of the functional, which is calculated from the results of solving the direct and adjoint boundary problems and is determined by integrating the squared difference of the actual data for a certain processing time. Applying the appropriate methods of minimization by the found gradient, the direction of the search is set, the step in this direction is determined, and the reservoir properties of the layer are refined based on the iterative formula established by the required unknown coefficients. This completes the first iteration of the algorithm for solving the direct and adjoint problems, and the value of the functional is calculated. The plane problem is solved repeatedly in accordance with the updated value of the capacity and filtering parameters. They find the difference between the calculated and actual values of pressure in the well at different points in time and, on its basis, solve the problem of the connection boundary. The value of the derivative of the functional is again determined. The layer parameters are specified again and the value of the functional is calculated. If after the first and second iterations the found values of the functional differ little, then the solution of the inverse problem (direct and adjoint problems) is considered to be completed. Otherwise, there is a transition to the third iteration, and so on. As a result, the values of the filter capacity parameters are refined in all elementary memories of the layer from the solution of the inverse problem.

The implementation of the determination method makes it possible to purposefully and effectively refine hydrodynamic models of filtration processes in a gas condensate reservoir under conditions of incompleteness and unreliability of the initial geological and mining data, as well as in order to improve the forecast of technical and economic production indicators and increase the yield of reservoir hydrocarbons, the reservoir development system is implemented in each period development and provides for appropriate regulation.

The correct definition of technical and technological indicators of the development of gas fields is mainly determined depending on the degree to which the actual conditions of the production well are taken into account. Therefore, the need to take into account most of the main factors that affect the dynamics of the movement of a gas-liquid mixture in the development process requires a comprehensive consideration and study of the system of equations describing the joint movement of gas in the reservoir and wellbore. and complementary initial and boundary conditions. In this regard, a method was developed and implemented for identifying the parameters characterizing the flow of gas in the reservoir and the wellbore, which is deformed according to the wellhead data, using the example of a specific reservoir model, taking into account the dynamic relationship of the reservoir-well system.

Thus, taking into account the dynamic relationship of the reservoir-well system, based on the equations of the thermodynamic balance of motion and the phase state of the gas condensate mixture in the reservoir and the wellbore, a theoretical basis was created for modeling the process of processing gas condensate deposits using known values of wellhead parameters in the depletion mode, the possibilities of predicting the technical -technological indicators of processing, a method for determining the parameters of the filtering capacity has been developed.

**Chapter 7** deals with the determination of rock filtration-capacity parameters and their solutions according to the minimum of the function between the measured and calculated values of the wellbore pressure at different times in the production well of natural gas condensate fields.

The efficiency of hydrocarbon deposits development requires the use of hydrodynamic or hydrothermodynamic models (taking into account the physicochemical properties and mass transfer of formation fluid phases) based on the theory of multiphase filtration. Also, the models of multiphase hydrodynamic filtration used must be adapted to reservoir conditions during processing and, as a result, must provide a correct forecast of the indicators of the processing process for a certain period of time and process control. From this point of view, an adequate assessment of reservoir conditions based on real indicators of the process of operating wells in oil and gas condensate fields, the reserves of which are difficult to recover, and a reliable forecast of technical indicators

The correct choice of the functions of relative phase permeability (RPP) of fluids in the process of multiphase flow has a direct impact on the reliability of the forecast of technological parameters of gas condensate deposits and the effective control of the technological process as a whole. In this regard, there is a need to include accurate RPP methods of fluid functions in reservoir treatment.

In this regard, the determination of the functions of relative phase permeability (RPP) included in the hydrodynamic model of the filtration of a gas-condensate-water mixture is studied as a variational problem of the minimum of the functional, determined from the integral of the square of the difference between the measured (or known from the history of development) pressure values and calculated from the solution of the corresponding hydrodynamic problem at different times. In this case, it is assumed that the gas condensate layer is operated in the injection mode, and a central well of radius $r_c$, operating with the production of $Q(t)$ , has opened the height $h$ of the productive layer. Water is injected from the boundary at a pressure of $p_k(t)$, through the injection well. The problem of radial symmetric plane parallel flow of gas-condensate-water mixture to the central well (straight problem) is modeled within the system of equations of three-phase three-component hydrodynamic model and included in their expressions for identification of NPC functions included in the system.

$$f_g(s_g) = \alpha_1 s_g^{\alpha_2},\ f_k(s_g, s_w) = \alpha_3((1 - s_{cw}) - (s_g + s_w))^{\alpha_4},$$
$$f_w(s_w) = \alpha_5 s_w^{\alpha_6}, \quad (38)$$

The solution of a straightforward problem is required to determine such values of unknown $\alpha_i$, $(i = \overline{1,6})$ parameters

$$J(\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6) = \int_0^{\bar{T}} [p(r_c, t) - p_c(t)]^2 dt + \varepsilon \left( \sum_{i=1}^{6} \alpha_i^2 \right) \quad (39)$$

give a minimum to the value of the function. Here $p(r_c, t)$ - the value of well pressure calculated based on the solution of a straight line; $p_c(t)$ - actual value of well pressure known from mining data; $\varepsilon$ - regulation parameter.

A problem is added to the straight line under consideration, the gradient of the function (20) is calculated as a result of their joint solution, and to determine the unknown coefficients sought

$$\alpha_i^{k+1} = \alpha_i^k - \lambda_i^k \frac{\partial J(\alpha_1^k, \alpha_2^k)}{\partial \alpha_i}, \quad i = \overline{1,6} \quad (40)$$

the iteration process is established $\lambda_i^k$ step of the gradient method). The solution algorithm for determining the RPP functions is defined as follows: $\alpha_i$ $(i = \overline{1,6})$ the initial value of the parameters is given and the straightforward problem is solved by the finite difference method based on the known development date of layer $[0, \bar{T}]$, and the layer pressure and gas, water, and condensate distribution are determined at different steps. The unknown parameters (40) are determined by the iteration process. The iteration procedure for determining the parameters continues until the values of the function in the two adjacent iterations compensate for the given accuracy.

Based on the mining data (measured values of well pressure), the identification of RPP functions for water, gas and condensate in the submerged regime gas condensate layer adapts the hydrodynamic model to real conditions by increasing the accuracy of forecast calculations.

The productive horizons of hydrocarbon deposits, as a rule, have a complex structure, and its reservoir properties differ both in the reservoir cross section and along its length. The forecast of technological indicators of layer processing strongly depends on its heterogeneity. Therefore, the question of the possibility of their determination is considered one of the important problems in the theory and practice of hydrocarbon field development. From this point of view, the problem of identifying the reservoir parameters of an inhomogeneous gas condensate reservoir in the depletion mode was studied and, on its basis, the task of determining the total change in the reservoir permeability along the height of the minimum of the functional, determined from the integral of the square of the difference between the calculated and measured production values by the change in processing time, solved as a variational problem.

A calculation scheme has been developed, and numerical calculations have been carried out. To check the reliability of the obtained solution, the solution of a simple problem of commissioning a gas condensate well with a constant pressure was considered as a standard and, as a result, taking into account the effect of non-primary due to permeability, the change in well productivity over time was determined. The corresponding inverse problem was solved and the reservoir heterogeneity parameter was determined with high accuracy according to the forecast of changes in well productivity over time.

Also, the problem of identification of filtration-capacity parameters of non-homogeneous gas condensate layer with depletion mode was studied and based on it the problem of determining the sufficiently general change in the permeability of the layer height was determined from the integral of the square of the difference between the calculated and measured production values solved as a matter of variation. The calculation scheme was developed, numerical calculations were performed. In order to test the reliability of the obtained solution as a standard, the solution of the direct problem of commissioning of a gas condensate well at constant pressure was considered, and as a result, the productivity of the well changed over time, taking into account the effect of non-priming capacity. The corresponding inverse problem was solved, and the identification of the heterogeneity parameter of the formation was performed with high accuracy according to the data of the forecast of well productivity change over time.

In the process of extraction of reserves of deep gas fields, reservoir rocks are subjected to inelastic (relaxation and creep) deformations, quantitatively and qualitatively different from the elastically deformed state, under the action of rock pressure with a decrease in reservoir pressure. Thereby, there is a need to build a gas-dynamic percolation model that can adequately describe the process of field development under conditions of inelastic deformation of rocks.

In this regard, to build a gas-dynamic model of filtration in a gas reservoir subjected to relaxation deformation, the problem of real gas leakage into a central well of a known radius, operating with a certain production, from a circular reservoir with a certain radius and height is considered.

Dependence of porosity and permeability of rock on pressure accepted as

$$m = m_0 e^{-\frac{t}{\tau_m}} + \frac{m_0}{\tau_m}\int_0^t e^{-\frac{t-\tau}{\tau_m}} e^{\beta_c(p-p_0)} d\tau,$$

$$k(p) = k_0 e^{\alpha_k(p-p_0)}. \qquad (41)$$

Here $m_0$ - initial porosity; $\tau_m$- porosity relaxation time; $\beta_c$- coefficient of elastic compression of the rock; $k_0$- initial conductivity value; $\alpha_k$- is a coefficient that takes into account the change in conductivity depending on pressure.

In order to identify the definition of unknown coefficients $\tau_m$, $\beta_c$ and $\alpha_k$ included in the expressions of reservoir properties according to historical processing data functional minimization of the functional built for a certain period of development according to the square of the difference between the calculated and actual values of the wellbore pressure was realized.

Based on the initial data of a hypothetical model of a gas reservoir, the identification values of the desired parameters were established as the value of the functional approaches zero, as well as the possibility of forecasting performance of indicators for any duration of development.

Thus, a method for the parametric identification of a three-phase hydrodynamic model is proposed to determine the functions of the relative phase permeabilities of the filtration of the gas-condensate-water system according to the mining data of the formation operation process, as well as an identification method for determining the permeability and porosity of the formation undergoing relaxation deformation, according to historical operation data processed on the basis of a real model of gas percolation in the gas regime. These methods make it possible to ensure high accuracy in predicting changes in well productivity over the development period. At the same time, the included identification method for determining the parameters of a heterogeneous gas condensate reservoir imitates a real adjustment in the management of the development process in terms of adjusting the forecast of technical and economic production indicators.

In this regard, based on the real gas filtration model in the gas mode, the issue of identification of the permeability and porosity of the layer subjected to relaxation deformation according to the developed data was considered and the possibility of correcting the forecast of development parameters at any stage of development was realized.

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## THE MAIN RESULTS

Comprehensive theoretical research of methods of modeling the process of interaction with gaseous and liquid agents in the development of gas condensate and oil condensate fields, taking into account the phase state of reservoir fluids, studied the basic laws of complex filtration processes in the reservoir, developed new methods to improve development efficiency was proposed. This time:

1. Theoretical basis of multicomponent filtration models has been developed, which allows to correctly assess the effectiveness of methods of interaction with hydrocarbon gases and water-gas mixture, as well as hot liquid hydrocarbons and gases in the pressure range below the maximum condensing pressure in the gas condensate layer in the development of hydrocarbon resources.

2. At the final stage of the gas condensate layer development, the process of creating a volume of retrograde condensate mixed with ethane gas in the formation and subsequent injection of separation gas was identified. Ethane gas is justified in providing a layer development efficiency by allowing the system to be saturated with liquid hydrocarbons where two-phase leaching occurs above the

crisis value by dissolving in retrograde condensate in the continuous mass exchange between phases.

3. Based on the three-phase multicomponent filtration model, the technological parameters of the depletion regime and the oil-water displacement regime in the operation of the oil-bearing gas condensate layer with the horizontal well without gas flow were compared and the main rate of oil extraction in the water-displacement mode increased sharply. . It is justified to carry out the operation of the oil tank with gas-free debit in the first stage of development in the mode of depletion, and in the next period in the mode of pumping oil with water.

4. Based on the results of the calculation of the two-phase two-dimensional mathematical model, a technological method was proposed to return the separated gas extracted from the gas cap to the water-oil boundary level at the water-oil boundary level during the development of oil-bearing gas condensate fields. The potential for evaporation of not only the moving oil but also the capillary-bound oil and, consequently, the development efficiency of the formation has been identified.

5. Evaluation of the effectiveness of the methods used to increase the oil recovery factor of the oil-bearing gas condensate layer was studied and it was determined that the anisotropic layer is more effective than other methods. .

6. Based on the joint solution of gas condensate mixture flow equations in the reservoir and wellbore, a calculation method has been proposed that allows to predict the flow conditions of the condensate mixture and the reservoir pressure and other technological parameters of development according to the wellhead data. The process of flow of gas condensate mixture into a homogeneous anisotropic bed was simulated and the effect of retrograde condensate accumulation in the wellbore zone of the bed opening and incompleteness of the well was assessed.

7. Methods for identification of variability determination of leakage-capacity parameters and relative phase conductivity

functions of gas condensate system due to changes in actual data of operational parameters of natural mode single or multilayer field have been developed.

The proposed technological developments in the dissertation and their calculation methods can be recommended for application in the design of oil, gas condensate and oil and gas condensate fields, the calculation of their reserves.

**The main results of dissertation are published in the following academic papers of author:**


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## Personal contribution of the author:

The [3-12, 18-23, 25,26, 28-35]   are peformed by author on his own;

In the [9-11,13,17,24,27] the author  participated in the formulation, decision and analysis of the issue;
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