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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

METHODS TO INCREASE THE EFFICIENCY OF THE DEVELOPMENT OF GAS CONDENSATE FIELDS

Speciality: 2525.01 – "Development and exploitation of oil and gas fields"

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GENERAL DESCRIPTION OF THE WORK

The actuality and study degree of the topic. The experience of developing gas condensate deposits shows that the extraction possibilities of gas and gaseous liquid are characterized by low indicators, and as a result, the volume of gas and gaseous liquid remaining in the Earth's crust is constantly increasing.

It is possible to find the optimal options for the extraction of natural hydrocarbon resources through the scientific summation of the results of the research of the reservoir systems and the collected development experience. In this regard, in terms of increasing the efficiency of development, mathematical modeling of reservoir systems and processes and, based on this, evaluating the advantages of applying multiple development methods in practice for reservoirs containing gas and liquid hydrocarbons are considered to be one of the most effective tools.

Looking at the possibilities of fundamental solution of the mentioned important problems of the gas industry, as well as the methods of physical and mathematical modeling of formation processes and the creation of hydrodynamic bases of various types of methods of influence on productive layers for the assimilation of hydrocarbon resources based on them, including the formation for increasing the condensate yield of layers with various hydrocarbons and non-hydrocarbon gases solving the impact issues with also, the proposal of effective new well technology options in development is of scientific and practical relevance.

In this work, a number of theoretical issues that correctly reflect the complex filtering processes that occur during the development of gas condensate fields, as well as the issues of impacting the layer with various hydrocarbon and non-hydrocarbon gases to increase the condensate yield of the formations and investigating the construction options of horizontal wells for the absorption of liquid hydrocarbon resources, were solved.

Object and subject of research. The object of the research is gas condensate and gas condensate oil fields at various stages of development, and the subject is increasing the efficiency of field development by extracting condensate deposited in the formation at the final stage of development using various methods.

The purpose and main objectives of the study. The purpose of the research is to create new processing methods for the hydrogas dynamic modeling of the hydrocarbon and non-hydrocarbon gases impacting the reservoir at different stages of the development of gas condensate fields and the processes of working with horizontal wells.

The main issues of the study:

1. Creation of a theoretical basis that allows to evaluate the effectiveness of the process of impacting the gas condensate layer with hydrocarbon and non-hydrocarbon gases at pressures close to the initial condensation pressure and below the maximum condensation pressure.

2. In increasing the processing efficiency of gas and gas condensate layers, horizon investigation of construction options of zonal wells and evaluation of their application possibilities.

3. Creation of methods of parametric identification of hydro-dynamic models of gas and gas condensate layer development in depletion mode.

Methods of research. The problems were solved by applying modern methods of hydrogasdynamic theory, computational mathematics and mathematical physics.

The main provisions brought to the defense.

1. Development of a computational model and algorithm and its software implementation, which allows to evaluate the effectiveness of the process of impacting the gas condensate layer with hydrocarbons at a pressure close to the initial condensation pressure and non-hydrocarbon gases at pressures below the maximum condensation pressure.

2. Methods for solving hydrodynamic problems in investigating optimal design options for horizontal wells to increase the efficiency of gas and gas condensate reservoir development.

3. The method of parametric identification of the parameters characterizing the layer and fluids according to the change of the wellhead and well bottom data of the operation of the gas and gas condensate layer in depletion mode.

Scientific novelty of the study. The conducted complex researches and the generalization of their results made it possible to obtain the following scientific innovations:

1. A theoretical basis and algorithm were developed that allow to evaluate the effectiveness of the process of impacting the gas condensate layer with hydrocarbon and non-hydrocarbon gases at pressures close to the initial condensation pressure and lower than the maximum condensation pressure, and the software for predicting the technological indicators of the processing was created.

2. The process of developing the gas and gas condensate layer with a horizontal well is modeled within the framework of the balance equation of the hydrocarbon system percolation in the layer, flow in the wellbore, entering the horizontal barrel from the reservoir and their necessary initial and boundary conditions, and it is necessary to choose the optimal construction that ensures the effectiveness of the development, geological, technical and technological factors were evaluated and realized on the basis of specific examples.

3. The methods of parametric identification of the parameters characterizing the layer and fluids have been developed according to the changes in the wellhead and downhole mining data of the gas and gas condensate layer worked in depletion mode.

Theoretical and practical significance of the study. The carried out researches include proposing new technological methods on the basis of modeling the impact of hydrocarbon and non-hydrocarbon gases on the layers in order to increase the component yield of gas condensate layers, as well as evaluating the technical and technological indicators of the efficiency of processing gas and gas condensate deposits with horizontal wells. are empirically important studies aimed at the development of scientific-methodical foundations.

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

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

- At the II Republican scientific conference "Modern problems of informatization, cybernetics and information technologies" (October 26-28, Baku, 2004)

- At the II International Scientific Conference of young scientists and students "New directions of research in the field of Earth Sciences" (October 8-10, Baku, 2007)

- At the 5th international conference of young scientists and students on "Fundamental and applied geology scientific achievements, perspectives, problems and their solutions" (November 14-15, Baku, 2013)

- At the International Multidisciplinary Forum "Academic Science Week-2015" (November 2-4, Baku, 2015)

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

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

- At the scientific session dedicated to the 90th anniversary of the birth of academician Midhat Teymur oglu Abasov on the topic "Fundamental and applied problems of oil and gas field development" of the Department of Earth Sciences of ANAS, (Baku, 2016).

16 works have been published on the topic of the dissertation work, 6 of them are articles, 10 are conference materials.

The name of the organization where the work was performed. İnstitute Geology and Geophysics and İnstitute Oil and Gas of the Ministry of Science and Education of the Republic of Azerbaijan.

The total volume of the thesis with a separate indication of the individual structural parts of the thesis. The dissertation consists of 147 pages, including an introduction, 4 chapters, conclusions, and a list of 199 references. The dissertation work includes 5 figures, 32 graphs, and 4 tables. The volume of the dissertation with a signs on individual parts is Title - 354 , Table of contents - 2978 , Introduction - 7352 , Chapter I - 52690, Chapter II - 36295, Chapter III - 41338, Chapter IV - 23775, Conclusion – 1967, excluding tables, graphs, figures, appendices and list of literature.

The total volume is 166749 signs.

BRİEF CONTENT OF THE WORK

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

In the first chapter, the problems of modeling formation processes during the development of gas condensate fields and various modifications of the methods of determining the phase state of the gas-liquid mixture, an overview of the researches on the problems of increasing the efficiency of the fields development are given, and the necessity of studying certain group of issues that are important in increasing the efficiency of utilization of hydrocarbon resources is justified.

The filtration process of the gas condensate system is mainly modeled by a system of two-phase two-component and multi-component differential equations. The two-phase two-component model of filtration was first proposed by M. T. Abasov (1963), F. G. Hasanov (1963) and B. Knyazev (1963), S. Neville (1963). Accordingly, the entire hydrocarbon mixture is separated into potential gas and potential condensate, and each of them is assumed to be in both phases under reservoir conditions. The multi-component model of gas condensate system filtration considers the system filtration as a two-phase multi-component movement with a phase transition. This direction was included in the researches of P.Collins (1964), Y.P.Zheltov (1962), M.D.Rozenberg (1963), B.N.Nikolayevsky (1965), A.K.Kurbanov (1964), K.Kh.Kouts (1980) and others.

The calculation method of determining the thermodynamic parameters included in the two-phase two-component model using isothermal difcondensation, equation of state and pseudo-components was proposed by M.T.Abasov, Z.Y.Abbasov, G.I. Dzhalalov and Kh. A. Feyzullayev (2006).

The calculation method for determining the parameters characterizing the physical properties of the phases included in the multiphase multicomponent filtration model depending on pressure, temperature and composition - the supply pressure and one or another uniform equation of state of the mixture - was introduced by A.Y. Hamiot, R. Reed, T. Sherwood, K.N. Coats, G.S. Stepanova, G.R. Gurevich, A.I. Bruysilovsky (2002), N.M. Viboronov, E.D. Karlinsky, A.I. Shirkovsky and others. In the pressure delivery method, the phase equilibrium constant of the components according to the phases is approximated depending on one parameter characterizing the pressure, temperature and composition - the delivery pressure.

The principle of calculating the induced pressure is that the initial system is replaced in the form of a binary model and the sought parameter is calculated accordingly. The missing aspect of the described approach is the inconsistency of the thermodynamic quantities of phase density and equilibrium constant. This factor leads to calculation errors in the crisis pressure and temperature regions, as well as at the boundary of single-phase and two-phase regions. The approach based on the use of the equation of state for gas and liquid phases has numerous advantages over the shortcomings of the system of thermodynamic relations described above. Currently, there are various modified equations of state that allow full consideration of the real property of phases. All proposed and developed equations of state are divided into two main types - polynomial and cubic.

Among the multi-coefficient equations of state, the eight-coefficient Benedict-Webb-Rubin equation and its most successful modification, the eleven-coefficient Starling Khan equation of state, are widely used in modeling the vapor-liquid equilibrium of mixtures and the thermal-physical properties of light hydrocarbons. However, multi-coefficient equations are quite complex, and iterative procedures are required to determine the roots of these equations.

Basically, cubic (relative to volume) equations of state are more convenient for engineering calculations. Their theoretical basis is the well-known Van der Waals equation of state. Van der Waals-type equations of state differ positively from multi-coefficient equations by their simplicity and the possibility of analytical determination of roots. In this case, cubic equations of state often both retain a certain advantage and surpass multi-coefficient equations in terms of the accuracy of calculating the thermodynamic properties of pure substances and their mixtures.

A more precise modification of the van der Waals equation is the Peng-Robinson (PR) equation of state. This cubic equation of state is the most widely used type of modeling of the properties of natural gas-condensate-oil systems. However, experience has shown that this equation of state leads to certain errors both in calculating the phase state at pressures above 30 MPa, as well as in modeling the pVT properties of the vapor (gas) and liquid phases of artificial (i.e. specially created for research purposes) and natural mixtures for gas-condensate mixtures with a significant content of C_{5+} components. Usually, the density of the vapor (gas) phase is overestimated, and the density of the liquid phase is underestimated.

Z.Y.Abbasov, A.I.Bruysilovsky equations of state were proposed, allowing to calculate pVT properties of natural oil and gas mixtures at pressures up to 100 MPa and temperatures up to 200 °C with accuracy sufficient for engineering purposes (calculation of reserves, field development project).

Based on the theory of multi-phase multi-component filtration, an analysis of the evaluation of effective technologies was given based on the interpretation of the current works in order to increase the condensate yield in the formation during the development of hydrocarbon fields, and the importance of solving a number of technological issues of the evaluation of the possibilities of removing the retrograde condensate collected in the formation and the bottom zone of the wells was substantiated.

From this point of view, the multicomponent filtration of real gas-condensate systems and the change of its phase state (pVT properties) depending on pressure, temperature and composition are realized with the help of the equation of state. It is necessary to solve innovative problems of hydrocarbon deposits development and to find their solution as a result of application of high-speed computer technology with the help of numerical methods.

In this context, in order to solve the issues of working gas condensate fields, complex researches were conducted with the hydrodynamic model depending on the working conditions and the general regularities of the working efficiency of gas condensate fields were determined and the interpretation of the main points of the practically significant results of solving the considered issues were included in the next chapters.

In the second chapter, for granular collectors, the problems of impacting the layer with gas enriched with liquid hydrocarbons and non-hydrocarbon gases in the pressure interval below the initial condensation pressure and above the maximum condensation pressure were solved.

The main processing method of gas condensate deposits is based on the use of natural reservoir energy. This is due to the fact that such processing requires low costs and a sufficient gasification coefficient (up to 90%) is obtained, but at this time numerous shortcomings are formed. One of the most serious problems is the accumulation of retrograde condensate in the formation and in the wellbore zone. That is, the loss of a large amount of liquid hydrocarbons. As the most classic example, it can be shown that the coefficient of condensate production for the end of the depletion regime of the Bulla-sea field is 29% of the initial reserve. Except for a few of the numerous methods for increasing the condensate yield, others are not applied in gas mining practice due to high capital and operating costs. From this point of view, the scientific justification and application of gas condensate fields operation and methods of impacting layers that require minimal cost and are efficient enough to increase the extraction of gas condensate reserves are of utmost importance.

The composition of the gas condensate system in the well bottom zone differs sharply compared to the current composition of the formation mixture. Therefore, the process of mass changes between the gas and liquid phases in the wellbore zone differs dramatically from the processes occurring in the field in general. Therefore, when the formation pressure is above the maximum condensation pressure, the enriched gas phase enters the wellbore zone (slightly low pressure) from the parts of the formation far from the well (slightly high pressure). By keeping the formation pressure above the maximum condensation pressure, the enriched gas phase produced from the well can be returned to the formation with a percussive well. In this context, the issue of injecting the gas obtained by adding a certain amount of light liquid components to the "dry" hydrocarbon gas collected after the separation of C_{5+} hydrocarbons from all the gas taken from the reservoir under pressure and pushing the reservoir to the operational wells of the gas condensate system is considered. In order to evaluate the efficiency of the application of the method of injecting gas enriched with light liquid hydrocarbons during the development of a concrete gas condensate layer, the exhaustion mode of the considered field was developed up to the allowable layer pressure, and a comparison was made with full and partial cycling-process options. It was determined that in the creation of hydrocarbons, 20% of the reserves of hydrocarbons of the formation can be returned to the formation and injected as the optimal variant of processing, and its production results are comparable to the results of the traditional cycling process and partial cycling process. In the general context, the values of gas and condensate results of the method vary in the intermediate value range of the results of the partial cycling process and the traditional cycling process.

Among the various methods considered possible for increasing the condensate yield of gas condensate fields, the most widespread is the method of injecting "dry" gas extracted from the formation into the formation to maintain the formation pressure. The prediction coefficient of the condensate extracted from the formation by this method is the highest. However, one of the disadvantages of the method is that the gas injected into the bed cannot be used for a long time. Experiments and mining studies confirm the feasibility of using non-hydrocarbon gases and their mixture with hydrocarbon gases to maintain formation pressure, and nitrogen and carbon dioxide can be used as non-hydrocarbon gas. In order to increase the condensate yield coefficient, it is important to qualitatively assess the effectiveness of different processing options, including the application of non-hydrocarbon gases and their mixture with hydrocarbon gases, which are recommended to be applied in the development of gas condensate deposits. In this context, the exposure to non-hydrocarbon gases - nitrogen (the first case) or carbon dioxide (the second case) is considered. The total volume of injected gas constitutes the main part of the total production produced from the reservoir during operation. In the first case, nitrogen was used to maintain formation pressure. During the entire period of development, 972 million m3 of nitrogen was pumped into the layer. In this case, the forecast coefficient of the condensate that can be extracted from the formation was equal to 71.7%. In the second case, carbon dioxide was used to maintain the formation pressure and its amount injected into the formation was 1024 million m3. In this case, the final condensate removal rate was 74.2%. In order to evaluate the effectiveness of injecting non-hydrocarbon gas (nitrogen or carbon dioxide) into the gas condensate layer, a comparison was made with the method of injecting dry gas. The final condensation coefficient obtained when the layer is exposed to nitrogen and carbon dioxide is comparable to the results of the "dry" gas exposure option. Certain limitations in obtaining dry and carbon dioxide and their high prices make it necessary to give priority to the use of nitrogen as an economical alternative for maintaining reservoir pressure.

When gas condensate fields are developed mainly at the expense of reservoir energy, when the reservoir pressure drops below the initial condensation pressure, high molecular components dissolved in the gas phase gradually separate from the gas phase and precipitate in the reservoir, i.e. retrograde phenomena occur. The immobile liquid phase accumulated in the pores resists the gas flow to the wells, and a gradual decrease in production due to gas and condensate occurs. At a certain stage of development (mainly in the decline and final stages), a sharp decrease in productivity worsens the efficiency indicators. One of the promising methods of removing the hydrocarbon condensate deposited in the formation is the method of impacting the formation with non-hydrocarbon gases (nitrogen or carbon dioxide) in the "dry" gas content. This method has been experimentally validated in a reservoir model of natural and artificial porous media and it has been determined that when 22% nitrogen is added to "dry" gas or 30% carbon dioxide is added to "dry" gas, the evaporation capacity of the precipitated condensate is almost the same as the evaporation of condensate with "dry" gas.

That is, it is possible to remove a certain part of the "dry" gas contained in the condensate deposited in the layer by several times impacting it with those gases. However, experimental studies fail to take into account several features of the multidimensional flow of the gas-condensate mixture into the wells. In this regard, as a development of the mentioned idea, taking into account the real conditions of the gas condensate layer, the theoretical investigation of the effect of non-hydrocarbon gases in the "dry" gas composition in the specified ratio has practical relevance. From this point of view, the evaluation of the effectiveness of impacting the gas condensate layer in the final stage of processing with "dry" and certain proportion of non-hydrocarbon gas is considered. After working from the maximum condensation pressure to the low pressure of the deeply located Bulla-sea gas condensate field in the example of the VII horizon of the V block, numerical calculations of compression of the retrograde condensate into the production wells were carried out and based on the prediction of the technological indicators of the development, it was determined that the "dry" gas in the depleting layer contains non- - exposure to hydrocarbon gases (nitrogen or carbon dioxide) (in two appropriate versions) leads to a sharp increase in the condensation coefficient compared to the exhaustion mode of processing. The calculation results of retrograde condensate removal in the two relevant options of the effect are almost indistinguishable from each other, and it is considered promising to choose any one of them based on economic indicators.

In the third chapter, the issues of researching the construction options of horizontal wells, the distribution of the lengths of the horizontal pipes along the height of the formation and the impact of the anisotropy of the formation on the productivity of the well were solved[1].

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[1] Maharramova, S.D. Modeling the gas flow process in a settled mode in a horizontal well // – Baku: Azerbaijan Oil Industry, – 2023. No. 2, – p.21-27.

Initially, in the stasionary mode, the issue of gas flow to the horizontal well with the length of the wellbore in the general case L on the plane located at a certain distance $r_0 (0 \leq r_0 \leq 2r_k)$ from the heel plane of the layer in a homogeneous circular anisotropic layer is considered (figure) and is modeled by the following system of equations:

- Continuity equation

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{k_r p\beta}{\mu Z p_{at}}\frac{\partial p}{\partial r}\right) + \frac{\partial}{\partial z}\left(\frac{k_z p\beta}{\mu Z p_{at}}\frac{\partial p}{\partial z}\right) = 0,$$
$$D = (r_q \leq r \leq r_k, 0 \leq z \leq h), \quad (1)$$

- The equation of the flow rate of the gas entering the wellbore from layer

$$2\pi r_q \int_0^z \frac{k_r p\beta}{\mu Z p_{at}} \frac{\partial p(r,z)}{\partial r}\bigg|_{r=r_q} dz = -Q^w(z), \quad (2)$$

- The equation of motion in a wellbore

$$\frac{\partial p^w(z)}{\partial z} = FQ^w(z), p(r_q, z) = p^w(z), z \in \Gamma, \quad (3)$$

Here r, z - spatial coordinates; k_r, k_z- absolute permeability of the porous medium on the r and z; μ - gas viscosity coefficient; D - gas filtration area; r_q - the radius of the horizontal well contour; h - length of feeding contour; r_k - represents half the height of the layer ($r_k = h/2$); $p(r,z)$ and $p^w(z)$ - pressure in the reservoir and wellbore; $\Gamma = (z_{min}, z_{max})$ - the surface of the wellbore $L = z_{max} - z_{min}$ into which the flow enters; $Q^w(z)$ - production of gas entering from the surface of the wellbore L ; $Q(z)$ - production of incoming gas per unit length of the surface Γ of the wellbore L; $F = \frac{8\mu}{\pi r_q^4}$- friction function; $\beta = \frac{T}{T_{at}}$ - temperature correction coefficient; T and T_{at}- the temperature of the productive layer corresponding to the current and atmospheric conditions; Z - the gas compressibility coefficient.

It is assumed that the gas percolation line obeys Darcy's law and the flow in the wellbore is laminar.

By solving the system of equations (1)-(3) within the following boundary conditions

$$2\pi h \frac{k_z p\beta}{\mu Z p_{at}} \frac{\partial p}{\partial z}\bigg|_{z=0,h} = 0, \tag{4}$$

$$p(r_k, z) = p_k(z), \tag{5}$$

$$Q^w(z)|_{z=0} = Q_0 \tag{6}$$

unknown $p(r,z)$,$p^w(z)$ and $Q^w(z)$ functions are defined.

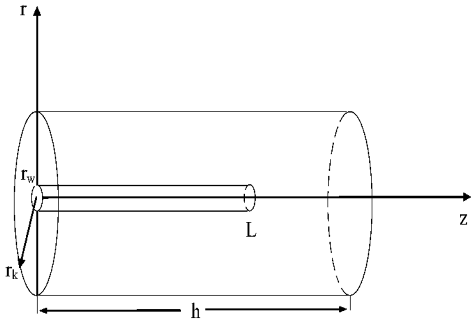

Figure. Description scheme of operation of the formation with a horizontal well

Based on the solution algorithm obtained by applying the finite difference scheme to the proposed calculation model, the distribution of the pressure on the surface of the barrel of the horizontal gas well and the flow rate of the gas entering the barrel from the surface of the horizontal barrel and other technological indicators were predicted within the known values of the parameters of the layer and the horizontal well. It was determined that the maximum discharge of a horizontal well is obtained in isotropic layers, that is, when the anisotropy coefficient is equal to unity[2]. At values of 0,1 and 0,6 of

[2] Maharramova, S.D., Salimova, S.A. Evaluation of techno¬lo¬gical indicators in the development of a gas-condensate layer with a fixed regime with a horizontal well // International scientific and practical conference on the topic “Heydar Aliyev and the oil strategy of Azerbaijan: Advances in oil and gas geology and geotech¬nologies”, – Baku: – May 23 – 26, – 2023, – p.831-835.

the anisotropy coefficient of the formation, for the same data of geological conditions and percolation-capacity properties of the formation, the productivity of the horizontal well decreases by 10,08 and 1,4 times compared to the productivity of the isotropic formation. Based on the dynamics of well production changes depending on the location of the selected horizontal barrel of a certain length on the formation height, it was determined that the well production increases when the horizontal wellbore moves from the ceiling of the formation to its central part, and decreases from the center to the ceiling. It was identified that as the length of the barrel of a horizontal well increases, the flow rate of gas entering it from the surface of the barrel decreases, and after a certain value of the length of the barrel, the length of the wellbore does not affect the flow rate of the well.

The issue of the gas condensate system flow in a horizontal well in a stasionary gas condensate reservoir was considered, and the gas condensate system flow in a horizontal well in a homogeneous circular anisotropic reservoir, on a plane located at a distance from the bottom plane of the formation, the length of the wellbore, in the general case L modeled by a system of equations:

$$\frac{1}{r}\frac{\partial}{\partial r}\{rk_r V_q(r,z,s_k,p)\} + \frac{\partial}{\partial z}\{k_z V_q(r,z,s_k,p)\} = 0,$$
$$D = (r_q \le r \le r_k, 0 \le z \le h), \tag{7}$$

$$\frac{1}{r}\frac{\partial}{\partial r}\{rk_r V_\kappa(r,z,s_k,p)\} + \frac{\partial}{\partial z}\{k_z V_\kappa(r,z,s_k,p)\} = 0,$$
$$D = (r_q \le r \le r_k, 0 \le z \le h), \tag{8}$$

$$p(r,z)|_{r=r_k} = p_k(z), \tag{9}$$

$$k_z\{V_q(r,z,s_k,p) + V_\kappa(r,z,s_k,p)\}\big|_{z=0,h} = 0, \tag{10}$$

$$2\pi r_q \int_0^z k_r\{V_q(r,z,s_k,p) + V_\kappa(r,z,s_k,p)\}\big|_{r=r_q} dz = -Q^w(z), \tag{11}$$

$$Q^w(z)|_{z=0} = Q_0, \tag{12}$$

$$a_1^2\frac{\partial^2 u_1}{\partial z^2} = \frac{\delta(z-z_{max})}{\rho_q}p(r_q, z_{max}) - \frac{\delta(z-z_{min})}{\rho_q}p(r_q, z_{min}), \tag{13}$$

$$a_2^2\frac{\partial^2 u_2}{\partial z^2} = \frac{\delta(z-z_{max})}{\rho_k}p(r_q, z_{max}) - \frac{\delta(z-z_{min})}{\rho_k}p(r_q, z_{min}), \tag{14}$$

$$u_1|_{z=0} = u_2|_{z=0} = 0, \left.\frac{\partial u_1}{\partial z}\right|_{z=L} = 0, \left.\frac{\partial u_2}{\partial z}\right|_{z=L} = 0 \qquad (15)$$

Here

$$V_k(r, z, s_k, p) = \left(\frac{F_k(s_k)}{\mu_k(p)a_k(p)} + \frac{F_q(s_k)c(p)\beta}{\mu_q(p)z(p)p_{at}}\right)\frac{\partial p}{\partial r},$$

$$V_q(r, z, s_k, p) = \left(\frac{F_q(s_k)p\beta[1-c(p)\overline{\gamma}(p)]}{\mu_q(p)z(p)p_{at}} + \frac{F_k(s_k)S_k(p)}{\mu_k(p)a_k(p)}\right)\frac{\partial p}{\partial r};$$

p, m, $s_k$and k - current pressure, porosity, condensate saturation and permeability, respectively; F_q and F_k- relative phase permeability for gas and condensate, respectively; $a_k(p)$ and $S_k(p)$ - the volume ratio of the liquid phase and the amount of gas dissolved in the liquid phase, respectively; $c(p)$ - amount of condensate in the gas phase; $\overline{\gamma}(p)$ - ratio of volume weights of condensate in liquid and gas phases under normal conditions; $\mu_q(p)$ and $\mu_k(p)$ - the viscosity of the gas and liquid phase, respectively; β - temperature correction coefficient; p_{at}- atmospheric pressure; h - layer height; r_q - the radius of the well; u_1, u_2- respectively displacement deformation of gas and liquid phases in any cross-section of the wellbore; a_1, a_2- speed of sound wave propagation in gas and liquid phases, respectively; r_k - the drainage radius of the well; ρ_q, ρ_k- is the density of the gas and liquid phases in the horizontal wellbore, respectively.

It is assumed that the gas-liquid mixture Q^w entering the horizontal wellbore is equal to the gas-liquid system produced from the well, and according to the pressure data and the known value Q^w, the values of p_w from the sistem of equations (11)-(12) are determined. Then, by solving the systems (7)-(10) and (13)-(15), the values of $p, s_k$and u_1, u_2 are found.

The new value of Q^w is determined by the expression

$$Q^w = f\left(\phi_1 a_1 \frac{\partial u_1}{\partial z} + \phi_2 a_2 \frac{\partial u_2}{\partial z}\right)$$

and the values of $p_w$are determined from the system (11)-(12) and the process is continued analogously. Here f - cross-sectional area of the horizontal wellbore; ϕ_1, ϕ_2 - the volume concentration of gas and liquid phases in the mixture in the horizontal wellbore.

Based on the proposed calculation algorithm, the distribution of the pressure on the surface of the barrel of the horizontal gas condensate well and the flow rate of gas and condensate entering the barrel from the surface of the horizontal barrel and the necessary technological indicators were predicted within the known values of the parameters of the layer and the horizontal well. It has been determined that the gradual reduction in the value of the value of the horizontal well that operates on the gas tank from the beginning to the end of the linguistic perforation reduces the efficiency of the gas and condensation that falls to the end of the well, and the increase in the volume of liquid columns on the well's deteriorates the processing indicators of the gascondensate well compared to the gas well. The location of the horizontal wellbore in the central part of the height of the gas condensate layer makes its productivity both for gas and condensate higher, compared to other locations. If the vertical permeability of the layer is low compared to the field permeability, it is not considered efficient to drill a horizontal well into it.

Also, the problem of gas flow into a horizontal well in an unsettled percolation regime in an anisotropic and weakly permeable productive layer closed on all sides was solved. The location of the horizontal well in the formation and the effect of its length on pressure and productivity were investigated, and the gas production coefficient was estimated by identifying the optimal length of the horizontal well drilled into the formation.

The process of developing a gas condensate layer with a horizontal well was modeled within the framework of two-phase two-component system equations of the filtration of the gas condensate mixture in the layer, the flow equations of the gas condensate system in the wellbore and their satisfaction of the necessary initial and boundary conditions, and the effect of the diameter and length of the well on the flow rate of the horizontal well was evaluated. It was determined that as the diameter of the horizontal well decreases, the optimal length of the well decreases and the pressure losses due to the increasing friction forces inside the well increase, which leads to a sharp decrease in the productivity of the well in terms of both gas and condensate.

In the fourth chapter, the issues of identification determination of the reservoir filtration-capacity parameters under conditions of isothermal filtration of the gas and gas-condensate mixture into the well in the gas and gas condensate fields operated in depletion mode were solved.

The adjustment and prediction of the development process in accordance with the full reality mainly depends on the adequate determination of the specific relative phase permeability functions of each well. For this purpose, initially, the problem of determination of relative phase permeability functions was solved on the basis of the two-phase two-component model of the gas-condensate mixture percolating into the well system. In this case, the variation problem is defined as the minimization of the functional J determined on the basis of the difference between the measured pressure value and the calculated value at different time periods:

$$J(\alpha_q,\beta_q,\alpha_k,\beta_k)=\int_0^T\sum_{j=1}^{n}\left[p(x_j,y_j,t)-p_f(x_j,y_j,t)\right]^2dt+$$
$$+\varepsilon(\alpha_q^2\ \ +\beta_q+\alpha_\kappa^2+\beta_\kappa^2)\Rightarrow min\ \ , \tag{16}$$

here $p_f(x_j,y_j,t)$ and $p(x_j,y_j,t)$ according to the measured and calculated values of pressure in the wells; (x_j,y_j) - coordinates of wells; α_l and β_l $(l=q,\kappa)$ - the numbers included in the empirical dependences of the relative phase permeability functions

$$F_l(s_l)=\begin{cases}\alpha_l\left(\frac{s_l-s_{l\,min}}{s_{l\,max}-s_{l\,min}}\right)^{\beta_l}, & s_{l\,min}\le s_l\le s_{l\,max}\\ 0, & 0\le s_l\le s_{l\,min}\end{cases} \tag{17}$$

and which need to be determined.

The functional $J(\alpha_q,\beta_q,\alpha_k,\beta_k)$ is a qualitative indicator of how accurately a real physical process is expressed by a mathematical model characterized by the value of the parameter $p_f(x_j,y_j,t)$. This time based on the qualitative indicator the control is carried with parameters α_l and β_l. The calculation value of $p(x_j,y_j,t)$ is determined by solving the problem of two-dimensional filtering of the gas condensate mixture into the system of wells working with $Q_{qj}(t), Q_{kj}(t)$ -debits. The outer contour of the field is impermeable. Before the wells are put into operation, the pressure is the same at all points of the reservoir, and the condensate saturation is homogeneous.

Identification determination of relative phase conductivities functions was approved in V block VII horizon of Bulla-deniz gas condensate field. The block under consideration was developed with ten wells. Using the local data of the wells, a method of adapting the hydrodynamic model to the real conditions of the gas condensate layer was proposed, and the accuracy of the forecast calculations for the next years of the development was ensured by determining the averaged relative phase conductivities functions according to the development of the entire horizon.

Gas and gas condensate deposits are mainly located in the deep layers of the Earth, and in such deposits, the reservoir pressure and temperature are high. The inaccuracy (or inability to measure) of information related to the wellbore and reservoir pressures of wells drilled into the deposits creates certain shortcomings in the regulation of production. In this regard, one of the important issues is the development of a method that allows to find well and reservoir pressure according to the wellhead pressure, and the identification of reservoir filtration parameters based on it. From this point of view, the problem of identification of the parameters of the formation that is deformed according to the wellhead parameters in gas filtration has been solved. It is assumed that a gas layer of height H in depletion mode is exploited with a central well of radius r_q with a flow rate $Q_0^w(r_q, t)$. The outer boundary of the layer is impermeable.Before the well is put into operation, the pressure at all points of the reservoir is $p_0(r)$. It is required to determine the permeability and porosity of the deformed layer according to the values of the wellhead pressure. The considered problem contains the real gas percolation equation in the formation and its initial-boundary conditions, the gas flow equation in the wellbore and its initial-boundary conditions, and the balance equation of the gas entering the wellbore from the formation, and from their joint solution, the unknown coefficients included in the empirical functions of permeability and porosity of the formation is determined based on the minimization of the input functional according to the square of the difference between the actual value of the wellbore pressure and the calculated value. At this time, the wellbore pressure calculated according to the known value of the wellhead pressure during any current period of development is taken as the actual value. During the solution of the problem, the values of the empirical coefficients are chosen arbitrarily as a first approximation, a certain number of iterations on the minimization of the input functional are required to obtain the true values of the function with the given accuracy.

Multilayer deposits can be developed by wells drilled into each horizon and by separate wells that open all productive horizons. In this regard, the creation of more accurate gas-hydrodynamic calculation methods for calculating the performance indicators of the operating system variants of multilayer deposits with the same system of wells and its filtration capacity determination of its characteristics remains an important and relevant issue.

It is assumed that a two-layer gas field is exploited by one well in depletion mode. It is assumed that the initial pressures in the first and second layers are p_{10}, p_{20}. Permeability, porosity and effective thicknesses of the layers are $k_i, m_i, h_i (i = 1,2)$. The effective distance between layers is L. In the first layer, wellbore pressure is applied. In the second layer, the wellbore pressure is determined by taking into account the hydrostatic pressure of the gas-liquid column in the well according to the wellbore pressure of the first layer. In the process of operation in the layers, it is required to determine the pressure distribution profiles and to find the total production of the well according to the pressure of the bottom of the well in the first layer, and also to find the production of each layer according to gas, and to determine the filtration-capacity parameters.

The prediction of the required development indicators under the given conditions is determined by the solution of the gas filtration equation in the layers satisfying the initial and boundary conditions:

$$\frac{1}{r}\frac{\partial}{\partial r}\left[r k_i(r,z) V_{qi}(r,t,z,p_i)\frac{\partial p_i}{\partial r}\right] + \frac{\partial}{\partial z}\left[k_i(r,z) V_{qi}(r,t,z,p_i)\frac{\partial p_i}{\partial z}\right] =$$

$$= \frac{\partial}{\partial t}\{[m_i(r,z)A_i(r,z,t,p_i)]\}, i = \overline{1,2}, (r,z) \in Dt \in (0,T), \quad (18)$$

$$p_i(r,z,t)|_{t=0} = p_{i0}(r,z),, i = \overline{1,2}, (r,z) \in D, \quad (19)$$

$$p_1(r,z,t)|_{r=r_q} = p_{1q}(t), p_2(r,z,t)|_{r=r_q} = p_{1q}(t) + \gamma L, \quad (20)$$

$$\left.\frac{\partial p_i(r,z,t)}{\partial r}\right|_{r=R_k} = 0, \left.\frac{\partial p_i(r,z,t)}{\partial z}\right|_{z=0,H} = 0, i = 1,2, t \in (0,T). \quad (21)$$

Here $V_q(r,z,t,s,p) = \left(\frac{p\beta}{\mu_q(p)z(p)p_{at}}\right)$; $A(p) = \frac{p\beta}{z(p)p_{at}}$; D - the filtering area; t - time; T - period of development; γ - volume weight of gas-liquid system; L - distance between layers; r, z - spatial coordinates; H - the upper boundary relative to the axis $z$of the first layer; r_q, r_k - the radius of the well and layer drainage radius, respectively; $i = 1,2$ - index denotes the first and second layers, respectively.

To solve the system (18), the pVT properties of the gas entering them should be calculated. For this, the system (18) it must be solved jointly with a system of differential equations expressing the process of differential depletion

$$\frac{d}{dt}\left[V_{mi}\rho_{qi}y_{ij}\right] = -Q_{qi}(t)y_{ij}, i = 1,2; j = \overline{1,N}, t \in (0,T), \quad (22)$$

and its initial conditions

$$p_i|_{t=0} = p_{i0}\,, y_{ij}\big|_{t=0} = y_{ij0}, i = 1,2; j = 1,2,\ldots,N-2, \quad (23)$$

and the equation of the state of the gas phase

$$p = RT\left[\frac{1}{V-b} - \frac{a}{V(V+c)}\right]. \quad (24)$$

Here $Q_{qi}(t)$ - production of the gas phase taken from the layers according to time; V_{mi} - volumes of porous media; y_{ij} - molar amounts of j component in gas phases in layers; ρ_{qi} - gas phase density in layers; N - the number of gas components; R - universal gas constant; T - gas temperature; V_i - gas volume in the porous medium by layers; a, b and c - the coefficients of the equation of state; t - time.

According to the results of the included solution method, the volume coefficient of the gas entering the system (18) is determined based on the change of the pressure and the component composition of the gas phase, and its viscosity is determined based on the value of the gas density. By taking the data obtained from the solution of the direct problem as the actual data of the development on layers, minimization of the value of the following function

$$J(\alpha_{11}, \alpha_{12}, \alpha_{21}, \alpha_{22}) = \int_0^T \int_0^{h_i} \sum_{i=1}^{2} \left[p_i(r_q, z, t) - p_{iq}(t)\right]^2 dzdt +$$
$$+ \varepsilon(\alpha_{11}^2 + \alpha_{12}^2 + \alpha_{21}^2 + \alpha_{22}^2) \Rightarrow min \quad (25)$$

has been realized for the determination of the and unknown parameters α_{1i} and α_{2i} included in the pressure-dependent empiric form of the porosity and permeability parameters

$$m_i(r, p_i) = m_{0i} m_i(p_i), m_i(p_i) = \left(\frac{p_i}{p_0}\right)^{\alpha_{1i}},$$
$$k_i(r, p_i) = k_{0i} k_i(p_i), k_i(p_i) = \left(\frac{p_i}{p_0}\right)^{\alpha_{2i}}, i = \overline{1,2}. \quad (26)$$

Here $k_i(p_i)$, $m_i(p_i)$ - pressure-dependent permeability and porosity of the layer, respectively; k_{0i} , m_{0i} - values of permeability and porosity at initial formation pressure.

The determination of the problem that is an adjunct to the direct problem (18)-(20) and their joint solution, based on finding the gradient of the function (25) and its implementation by constructing iteration based on the unknown coefficients included in the empirical dependence (26), allows the determination of the filtration-capacity parameters of each deformed layer with sufficiently high accuracy.

CONCLUSİON

Researches have been conducted in the direction of creating a calculation model that allows to evaluate the effect of hydrocarbon and non-hydrocarbon gases on the gas condensate layer at different stages of processing and the effectiveness of processing the layer with horizontal wells, new methods for increasing the efficiency of processing, and methods for determining the filtration capacity parameters. and when:

1. The theoretical base of the two-phase multi-component filtration model was developed, which allows to evaluate the effectiveness of the process of impact with hydrocarbon and non-hydrocarbon gases at pressures close to the initial condensation pressure and lower than the maximum condensation pressure in the assimilation of liquid hydrocarbon resources.

2. The necessary optimal volume of the part of the produced volume of the light liquid hydrocarbons reserve of the layer, which ensures the increase of processing efficiency in the effect of the gas enriched with light liquid hydrocarbons at a pressure level close to the initial condensation pressure, was estimated.

3. The possibility of increasing the gas and condensate transfer coefficients compared to the results of the "dry" gas impact on the gas condensate layer at a pressure level close to the initial condensation pressure with non-hydrocarbon gases is substantiated.

4. The efficiency of the retrograde condensate removal process was evaluated in comparison with the depletion mode of the development in the effect of the gas condensate layer at the final stage of development with a non-hydrocarbon gas mixture of different proportions in the "dry" gas.

5. The process of processing gas and gas condensate layer with a horizontal well is modeled within the framework of the joint combination of the balance equation of the hydrocarbon system percolation in the layer, flow in the wellbore, entering the horizontal barrel from the reservoir, and the geological, technical and technological factors necessary for choosing the optimal construction that ensures the efficiency of the development are determined.

6. According to the change of the actual data of the wellhead and bottom of the gas and gas condensate layer, methods of identification determination of its filtration capacity parameters are proposed.

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

The main content of the dissertation is reflected in the following published scientific works:

1. Abasov, M.T., Jalalov, G.I., Feyzullaev, H.A., Kuliev, G.F., Jakhrami, P.B., Maharramova, S.D. Determination of relative phase permeability functions during filtration of a gas-condensate mixture to a well system // Proceedings of the II Republican Scientific Conference "Modern Problems of Informatization, Cybernetics and Information Technologies", – Baku: – October 26 – 28, – 2004, – v. III, – p.3-5.

2. Maharramova, S.D. To increase the productivity of gas condensate wells, liquid propane development of their wellbore zone // II International scientific conference of young scientists and students "New directions of research in the field of earth sciences", – Baku: – October 8 – 10, – 2007, – p.52-53.

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The claimant's personal contribution in published scientific works related to the conducted research:

- [2-5, 12,14,15] - performed his work independently,
- [1,8] - participated in setting, solving and analyzing the problem.
- [6,7,9,10,11,13,16] - the share of participating in work is equal.

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