Research Article

Alexander K. Skiba*

Construction of a gas condensate field development model

https://doi.org/10.1515/comp-2020-0226
received November 26, 2019; accepted March 10, 2021

Abstract: This article has developed and verified a mathematical aggregated approximate model of developing a gas condensate field using a cyclic process. The essence of the cyclic process is to pump the drained gas into the productive formation to reduce the pressure drop into the deposit. This process allows for increased condensate recovery in the future. The model discussed in this article is a continuous dynamic system with control parameters. It is a modification of the dynamic aggregated model of a purely gas field, designed for planning for a sufficiently long period with limited information about the state of the reservoir (the initial flow rate of wells, the initial recoverable gas reserves, the initial reservoir pressure, the dependence of potential condensate content per unit volume of fatty gas on the reservoir pressure). A non-standard approach underlies the model construction. Logical simplifications and *a priori* assumptions about the processes occurring in the field during its development are at its core. The instruments in the model are the increase in production and injection wells and the proportion of injection wells involved in the production. The purpose of the article is to calculate various variants of the dynamics of the fundamental indicators of the development of a gas condensate field for a sufficiently long-term period at the stage of preliminary design.

Keywords: a continuous dynamic model of gas condensate field development, gas condensate field, cycling process, the strategy of development of gas condensate field, fatty gas extraction, dried gas production

*** Corresponding author: Alexander K. Skiba,** Department of Mathematical Methods of Regional Programming, Federal Research Center “Computer Science and Control” of Russian Academy of Sciences, Moscow, Russian Federation, e-mail: a.k.skiba@mail.ru

1 Introduction

Currently, we observe the following main trends in the development of the Russian oil and gas complex:

- an increase in the share of multi-component deposits;
- the transfer of the main production capacities to remote and hard-to-reach regions of the country;
- the development involves deposits with deep-lying productive strata and having complex mining and geological conditions;
- the Russian Federation’s distributed subsoil fund contains over 95% of the explored reserves of condensate and about 90% of its preliminary estimated reserves.

At the same time, the share of recoverable condensate reserves in our country is small, although gas condensate is a valuable raw material for the chemical industry. The priority tasks of the state are the full use of the potential of deposits, rational subsoil use, and advanced technologies [1].

An increase in the share of multi-component fields and the transfer of main production facilities to remote and inaccessible country regions characterize the development of Russia’s oil and gas complex.

The technology of gas condensate field development, based on the use of only the reservoir’s natural energy, leads to significant irreversible losses of gas condensate. If the gas contains little condensate or its reserves are small, the development of the gas condensate field proceeds in the usual way in the depletion mode.

For gas condensate fields operating in the depletion mode of reservoir energy, the loss of hydrocarbons (C5 and higher) reaches from 30 to 60% of their initial reserves. Maintaining reservoir pressure during field development above a point of the condensation start will prevent or significantly reduce condensate losses in the reservoir. We can achieve this effect by artificially maintaining reservoir pressure at the initial level. A recirculating gas method is called the cyclic process. As experience later showed, it is one of the most effective ways to combat condensate losses in the reservoir [2,3].

The cycling process, in which only a part of the extracted and dried gas returns to the reservoir, uses in foreign practice [4]. The rest of the gas, like all condensate, is sold. With a partial cycling process, the reservoir pressure decreases, which, in turn, leads to a partial release of liquid condensate in the reservoir. The cycling process also allowus, if necessary, to preserve the gas reserves of a given field for some time.

The cycling process technology allows us to increase the reservoir condensate recovery and liquid hydrocarbons by 10–35%. The duration of the process depends on economic calculations. If the effect of this technology reduces, the field is transferred to development without maintaining reservoir pressure.

This technology increases the time of successful field development by 10–15 years. The accumulated volume of gas condensate production during the operation of the field can increase by 1.5–2 times. At the same time, the accumulated volume of commercial production of natural gas remains virtually unchanged.

With an incomplete cycling process with a ratio of injected and recovered gas volumes of 60–85%, the decrease in reservoir pressure can reach 40% of the initial value. The predicted gas condensate recovery factor is 60–70%. When all dry gas produced at the field is injected into the reservoir, the initial reservoir pressure drops by 3–7%. Retrograde condensation is negligible. The predicted recovery factor of condensate from the reservoir with a complete cycling process reaches 70–80%.

This development system is economically feasible when the condensate content in the gas is more than 200 g/m^3.

In addition to the cycling process, there are other methods of maintaining reservoir pressure by injecting various agents into the reservoir: enriched gas, propane–butane fraction, non-hydrocarbon gas (nitrogen), water, and the mixed action of gas and water WAG (water–gas stimulation) [2].

The results of studies to improve condensate recovery during the development of gas condensate fields confirm the unconventional technology's applicability. These include the injection of nitrogen into the reservoir. In the Achimov deposits of the Urengoy oil and gas condensate field, a relative increase in condensate production is expected due to the injection of nitrogen into the reservoir by 40–50% [5].

The use of numerical and analytical reservoir modeling methods is the basis for long-term forecasting of the integrated development of gas condensate fields. Unlike complex numerical models built based on a large amount of input data, for long-term forecasting in uncertainties, they rely on simpler analytical models [6,7].

The development of hydrocarbon deposits is a complex national economic problem. From the beginning of the study of a deposit to its development, sometimes more than a dozen years pass. Geologists study the composition of the gas, the depth of the reservoir, the conditions of its occurrence, the contours of the gas-containing field, the reservoir properties of rocks, reservoir pressure, reservoir temperature, and many other parameters necessary for the subsequent development of the deposit. Among them, parameters, such as well flow rate, gas reserves, and the dependence of the potential condensate content per unit volume of fatty gas on reservoir pressure, are determined [8]. At this stage, using our proposed model, it is already possible to calculate long-term development options.

The received data are then sent to the design organization. There they are comprehended and processed. The task becomes more difficult in this situation. We must use proven models and build new models related to a particular deposit. The models are merged, and the development project is calculated for the short-term and long-term periods.

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We can draw the following conclusion: the shorter the forecast period, the more accurate it is [9,10]. There are objective reasons for this. These include the duration of the field development period, the inaccuracy of the initial data, the approximation and aggregation of models, the problems that arise with their docking, the lack of necessary data, the presence of uncertainties, chance, the human factor, and much more. After some time, the actual dynamic performance is compared with the forecast performance, and the development project is revised.

In this regard, the model proposed by the authors becomes relevant. With its help, it is possible to obtain various dynamic estimates of the fundamental development indicators at the preliminary design stage with a limited amount of input information.

All dynamic processes taking place inside the reservoir are pretty complex and multi-factorial. The dynamics forecast of the fundamental indicators of a gas condensate field occurs at the design stage of its development in the presence of a large amount of factual material.

The model proposed by the authors can be used much earlier at the preliminary design stage. For calculations, a limited number of data about the reservoir is required (initial flow rate of wells, initial recoverable gas reserves, initial reservoir pressure, the dependence of the potential condensate content on reservoir pressure). Before starting the field development design, we can obtain this information from geologists.

Using this model, we can calculate the dynamics of the fundamental indicators of a gas condensate field and determine the efficiency of its development, for example, profit. The proposed model plays a significant role in choosing one field from a group of deposits for further development. For each field, the optimal control problem is posed and solved. We compare solutions and choose a field with the maximum efficiency criterion. Another approach requires time, significant financial support, and additional solutions to many practical problems. Please note that solving optimization problems will be the subject of the following paper.

The main advantage of the model proposed by the authors is a small amount of initial data and the possibility of using them in calculations long before the start of field trial operation. It is essential when planning the development of a large group of gas and gas condensate fields with varying degrees of exploration.

The following section will construct a continuous aggregated dynamic model of the gas condensate field development using a cyclical process. We introduce notation for the considered parameters and write out formulas, some in differential form. A relationship is established between the parameters, represented by equalities and inequalities. We use some of the entered parameters as controls. We describe simplifications and *a priori* assumptions about the processes occurring in the reservoir, and for a better perception of this article, we give two figures. The first figure shows a schematic diagram of the development of a gas condensate field using a cyclic process. Another picture is a graph of the potential condensate content per unit volume of fatty gas. This dependence is typical for most gas condensate fields. This article describes a criterion for evaluating the effectiveness of developing a gas condensate field. Based on this criterion, we can formulate the optimal control problem.

Section 3 describes the results of a numerical experiment using a conditional example of a gas condensate field. In the first experiment, the development of a gas condensate field proceeds in depletion mode. The second experiment uses a complete cycling process. We compare and analyze the results obtained.

2 Gas condensate field model

Aggregated indicators of the corresponding technological processes underlie economic and mathematical models of hydrocarbon production. Problems and research tools determine the detailed level of the model description. When constructing an economic and mathematical model of a gas condensate field, the authors considered it necessary to reflect the essential and most characteristic features of their development:

- Non-linearity of changes in the fundamental technical and economic indicators;
- The time shift between the main expenses and the received income;
- Deterioration of mountain and geological conditions with the development of deposits.

The known papers [11–13] contain the basics of the technological design of developing a gas condensate. However, the detailing of some aspects of field development exceeds that required at the long-term planning stage. Therefore, such features are absent in the model.

Models developed for long-term planning use approximate dependencies and methods, primarily material balance methods. A non-standard approach is used based on logical assumptions, simplifications, and *a priori* assumptions when constructing a model. The proposed method can significantly reduce the input information required for accurate calculation. This method does not consider many features of the development of gas condensate fields. Still, it allows for sufficient accuracy to estimate such indicators as gas extraction, capital investments, operating costs, and many other factors.

From the point of conformity view with the actual physical process of gas condensate field development, the ratios underlying this model have some assumptions:

- The reservoir properties of the considered productive layer are close to ideal;
- The gas condensate production is estimated based on a limited amount of data (it means an *a priori* relationship between the fatty gas content in the total production volume and the pore volume of the reservoir occupied by dry gas);
- The uniform placement of production (production) and injection wells is accepted;
- The calculations made for an average well.

The aggregated models of oil and gas fields included in the imitation systems have been constructed on the same assumptions. These imitation systems have been developed at the Computing Center of the Russian Academy of Sciences. They were designed to draw up long-term plans to extract gas and oil for the respective groups of fields [14].

The optimization problem's commercial formulation is as follows: determine the strategy for involving reserves of deposits in the Russian economy for a given system of estimates for natural gas and gas condensate. It means to define in dynamics:

- rate of commissioning of production and injection wells;
- degree of dry gas return to the reservoir to increase condensate production.

Knowledge of these values allows us to determine the dynamics of various indicators of the development of a gas condensate field.

Let us now turn to the construction of a gas condensate field model. We introduce the following notation:

$N_1(t)$, $N_2(t)$ – injection and production wells at time t;

$N_1^*(t)$, $N_2^*(t)$ – the number of wells injecting dry gas into the formation and the number of wells producing gas from the reservoir at time t;

$n_1(t)$, $n_2(t)$ – commissioning of injection and production wells at time t;

$\beta(t)$ – a share of injection wells used as extraction wells ($0 \le \beta(t) \le 1$) at time t;

$q(t)$, q_N – production well flow rate and injectivity of injection wells at time t (injectivity of injection wells is assumed to be unchanged);

$Q_G(t)$, $Q_X(t)$, $Q_C(t)$, $Q_T(t)$, $Q_Z(t)$, $Q_K(t)$ – gas extraction, fatty gas extraction, dry gas extraction, commercial gas production, dried gas injection into the formation and condensate production at time t;

$\overline{Q}_T$ – maximum throughput of the pipeline;

$\bar{n}_1$, $\bar{n}_2$ – technological restrictions on the increment of injection and producing wells at each moment t;

$\overline{m}$ – a maximum financial possibility for the construction wells at each moment t;

$V(t)$, $X(t)$, $Y(t)$ – recoverable gas reserves, reserves of fatty gas, and reserves of dry gas at time t;

$p(t)$ – formation pressure at time t.

The initial values of the used variables mark with a zero at the top. These include:

N_1^0, N_2^0 – the initial number of injection and production wells;

q^0 – the extraction well initial flow rate;

V^0, X^0, Y^0 – the initial recoverable gas reserves, the initial reserves of fatty gas, and the initial reserves of dry gas;

p^0 – the initial formation pressure.

We assume that at the initial moment two equalities hold: $V^0 = X^0$ and $Y^0 = 0$. It means that the initial volumes of recoverable and fat gas reserves coincide, and dry gas has not yet entered the reservoir. It is assumed that $N_1^0 \ge 0$, $N_2^0 \ge 0$, $q^0 > 0$, $V^0 = X^0 > 0$, $p^0 > 0$.

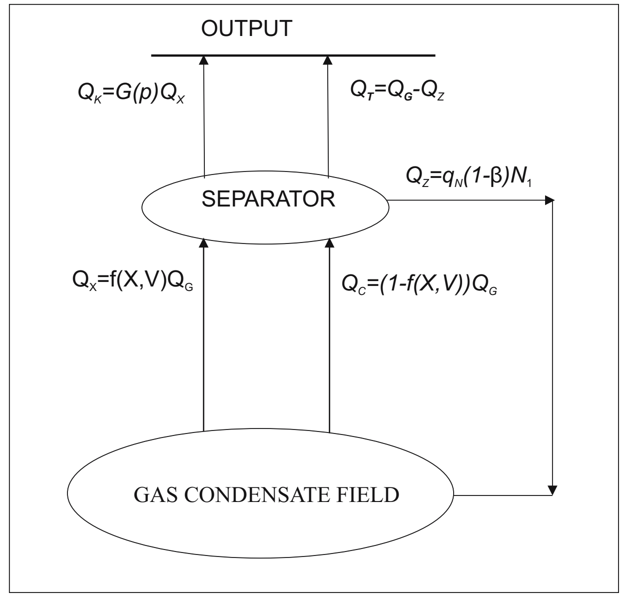

Figure 1: The scheme of cycling process application in the model of gas condensate field development ($Q_G = q(N_2 + \beta N_1)$).

The cycling process application scheme in the development model of the gas condensate field is shown in Figure 1. The essence of the cyclic process is the injection of dry gas into the reservoir to maintain reservoir pressure. Therefore, the reservoir contains dry and fatty gas. At any moment, the following equality holds:

$$V(t) = X(t) + Y(t). \tag{1}$$

It is obvious that the following double inequality holds:

$$0 \le X \le V. \tag{2}$$

We assume that the reservoir contains two independent fractions: dry and fatty gas. They do not affect each other. Dry gas does not degenerate and does not absorb condensate.

This assumption is controversial and criticized. There are arguments in favor of this assumption. Attempts to more accurately describe the dynamic processes of gas movement within the reservoir and the exchange of condensate between dry and fatty gas leads to a significant increase in input parameters, expensive research, and financial and time costs. This approach does not provide the desired accuracy and the ability to carry out calculations long before the start of field operation, such as at the preliminary design stage.

Let us continue the description of the scheme. We extract gas from the depths of the field in the amount of Q_G. It consists of dry and fatty gas:

$$Q_G = Q_C + Q_X. \tag{3}$$

Furthermore, all the produced gas enters the separator for subsequent complete drying. We extract condensate from it, which is then sold. Dried gas in the volume Q_G is distributed between the injected gas and commercial gas entering the pipeline for its subsequent sale:

$$Q_G = Q_T + Q_Z. \tag{4}$$

In the model, we neglect the volume of produced condensate compared to the amount of gas produced. There is a powerful argument for this.

The book of Gritsenko et al. [15] contains a table with the limiting values of condensate in reservoir gas. The smallest amount is in the Gazlinskoye field, 2 cm^3/m^3. The Artyukhovskoye field has the highest value – 1,300 cm^3/m^3. As a percentage, this is approximately 0.1%, which is a thousand times less than the volume of the gas itself. We neglect this volume of condensate.

Differential equations describe the dynamics of recoverable, fatty, and dry gas reserves:

$$\dot{V} = -Q_T; \tag{5}$$

$$\dot{X} = -Q_X; \tag{6}$$

$$\dot{Y} = Q_Z - Q_C. \tag{7}$$

We continue to describe the proposed model. The following differential equations describe dynamic changes in the well's fund values:

$$\dot{N}_1 = n_1; \tag{8}$$

$$\dot{N}_2 = n_2. \tag{9}$$

If part of the stock of injection wells participates in gas production, then the number of wells used to pump dry gas into the reservoir is determined by the following formula:

$$N_1^* = (1 - \beta)N_1. \tag{10}$$

The following formula determines the well stock used only for gas production:

$$N_2^* = N_2 + \beta N_1. \tag{11}$$

It is obvious that

$$Q_G = qN_2^*, \tag{12}$$

$$Q_Z = q_N N_1^*. \tag{13}$$

Extractions of fatty and dry gas, as well as condensate production, are calculated using the following formulas:

$$Q_X = Q_G f(X, V); \tag{14}$$

$$Q_C = Q_G(1 - f(X, V));$$

$$Q_K = Q_X G(p). \tag{15}$$

We will discuss the f and G functions subsequently. Neglecting the produced condensate volume in comparison with the gas volume, we calculate the production of commercial gas according to the following formula:

$$Q_T = Q_G - Q_Z. \tag{16}$$

Note that if we only use gas produced from the same field for injection, then

$$Q_T \geq 0. \tag{17}$$

If it is possible to use dry gas from other fields, we do not consider the last inequality. The pipeline's capacity limits commercial gas production through which gas is transported from the field.

$$Q_T \leq \overline{Q}_T. \tag{18}$$

To not complicate the paper with formulas, we will consider the throughput of pipeline $\overline{Q}_T$ to be a sufficiently large value.

As in the models of the gas and oil fields [16,17], a simplifying assumption is made about the proportionality in well flow rates, reservoir pressure, and recoverable gas reserve, i.e.,

$$q = \frac{q^0}{V^0}V, \; p = \frac{p^0}{V^0}V. \tag{19}$$

We obtain the differential equation from (19) and (5):

$$\dot{q} = -\frac{q^0}{V^0}Q_T. \tag{20}$$

A similar equation was obtained for a pure gas field, based on which interesting problems of optimal control [14,18] are solved.

The management of the gas field development process is carried out by selecting the parameters $n_1(t)$, $n_2(t)$, β at the interval $[0, T]$. They are subject to natural, technological restrictions, the simplest of which have the following form:

$$0 \leq n_1(t) \leq \overline{n}_1, \tag{21}$$

$$0 \leq n_2(t) \leq \overline{n}_2, \tag{22}$$

$$0 \leq \beta(t) \leq 1. \tag{23}$$

Conditions (21) and (22) we may supplement by a connecting inequality:

$$\alpha_1 n_1(t) + \alpha_2 n_2(t) \leq \overline{m}, \tag{24}$$

where $\overline{m}$ is a maximum financial possibility for the construction of wells; α_1, α_2 are positive coefficients.

If the cyclic process does not use gas from other fields, then the following more complex constraint is valid:

$$\max\left[0, \frac{q_N N_1 - qN_2}{N_1(q_N + q)}\right] \le \beta \le 1. \tag{25}$$

Let us describe in detail the output of restrictions (25). In this case, the injected dry gas volume of $Q_Z(t)$ does not exceed the produced gas volume of $Q_G(t)$ at time t.

$$q_N N_1^* \le q N_2^* \tag{26}$$

or

$$q_N(1-\beta)N_1 \le q(N_2 + \beta N_1). \tag{27}$$

We obtain from here

$$\frac{q_N N_1 - qN_2}{N_1(q_N + q)} \le \beta. \tag{28}$$

The left-hand side of the last inequality (28) is less than 1. However, it can be either positive or negative. Given the constraints (23), we obtain the double inequality (25).

Next, we describe the aforementioned functions $f(X, V)$ and $G(p)$.

$f(X, V)$ is a fraction of fatty gas in the extracted gas. This function is associated with the displacement of fatty gas from the formation by the injected dry gas. At the beginning of the development $f(X, V) = 1$, when the entire gas is completely displaced – $f(X, V) = 0$. When developing a field, the time function $f(X(t), V(t))$ does not increase monotonically. Generally speaking, the exact form of the function $f(X, V)$ before development is unknown. Concerning it, you can only make *a priori* assumptions. We describe in detail only two of them:

(a) Piston displacement of fatty gas by dry gas proceeds without mixing of gases, without a breakthrough of dried gas to the bottom of the wells working for production (N_2^*). After full extraction of the fatty gas, the dried gas enters all wells simultaneously. In this case, the function f depends only on the variable X:

$$f(X, V) = \begin{cases} 1, & \text{if } X > 0, \\ 0, & \text{if } X = 0; \end{cases} \tag{29}$$

(b) there is an instant uniform mixing of dried and fatty gases. In this case, dried gas instantly breaks through to the bottom of producing wells. The volumes of fatty and dried gases are proportional to their available reserves in forming the extracted gas. In this case:

$$f(X, V) = \frac{X}{V}. \tag{30}$$

The $G(p)$ function, the typical form shown in the graph in Figure 2, describes the weight content of condensate per unit volume of produced fatty gas depending on reservoir pressure. The numerical values of such a function are determined for each specific deposit as a result of laboratory experiments with gas samples at high-pressure installations [15]. A characteristic feature of the function $G(p)$ is that at a pressure p greater than the pressure of the start condensation p', $G(p) = G(p')$. For values of $0 < p < p'$, the function graph is an S-shaped curve consisting of a convex and concave part.

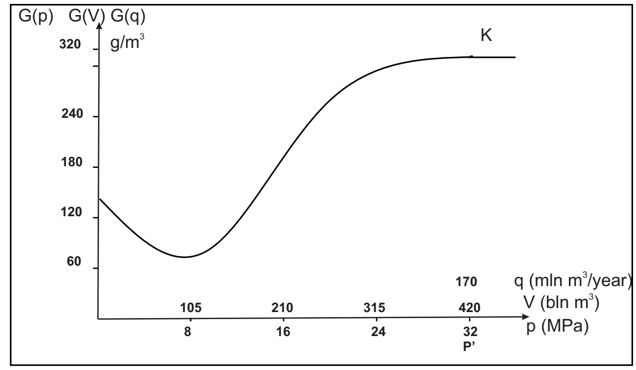

Figure 2: The potential contents of condensate per unit volume of extracted fatty gas.

The author investigated a similar curve in the article [19]. He got impressive results. Later in the English-language scientific literature appeared expressions such as "Skiba set" and "Skiba points."

We note a rather interesting fact. The world's first gas condensate fields were perceived as oil fields based on visual observations. This fact is associated with insufficient knowledge of retrograde phenomena during the development of the first gas condensate fields.

To complete the construction of the model, we describe the criterion for assessing the dynamics of the development of gas condensate fields. This article considers an approximate aggregated continuous dynamic model of a gas condensate field, which calculates different variants of cycling processes. This model implies the study and selection of a strategy for developing multi-component hydrocarbon deposits. As a criterion for assessing the effectiveness of the field development strategy, we take the maximum profit:

$$\int_0^T \{\varphi_G(t)Q_T(t) + \varphi_K(t) \cdot Q_K(t) - S(t)\}\exp(-\delta t)dt \to \max,$$

where t is the current time; T is the duration of the planning period; $Q_T(t)$, $Q_K(t)$ are current commodity gas and condensate extractions at time t; $\varphi_G(t)$, $\varphi_K(t)$ are current suppositional cost estimations of gas and condensate; $S(t)$ is a current cost for the field development, taking into account the deterioration of mining and geological conditions; δ is a discount factor.

The effectiveness of the development of Russian oil and gas resources in modern conditions is devoted to the scientific works of Academician Kryukov [20,21].

Let us clarify the previous functionality:

$$\int_0^T \{c_G Q_T(t)e^{\rho t} + c_K Q_K(t)e^{\mu t} - S_0^*(t)e^{\nu t}\}e^{-\delta t}\mathrm{d}t, \quad (31)$$

where c_G, c_K are market prices for natural gas and condensate at the initial time of the planning period; ρ, μ are growth rates of the prices for gas and condensate; ν is a growth rate of the current expenditures due to mining and geological condition deterioration.

The deposit development current costs are calculated using the formula:

$$S_0^* = l_1N_1 + l_2N_2 + k_1n_1 + k_2n_2, \quad (32)$$

where l_1, l_2 are operating costs per one injection well and one production well, respectively; k_1, k_2 are the capital costs per one injection well and one production well, respectively.

For the coefficients l_1, l_2, k_1, k_2 the values corresponding to the initial planning period $t = 0$ are accepted. This model does not consider the costs of creating and operating compressor facilities to ensure the injection and transportation of gas.

We have constructed a model.

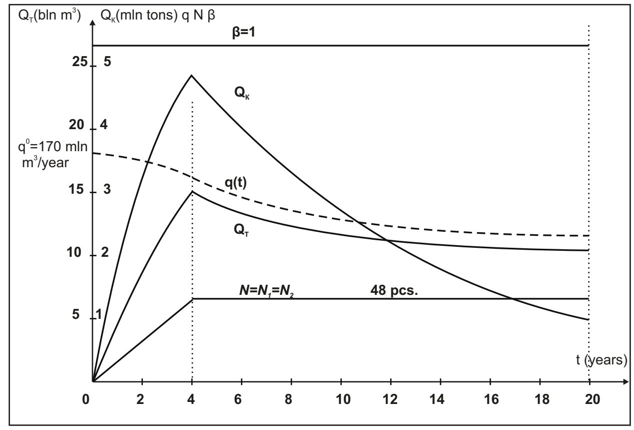

Figure 3: Main parameter dynamics of the development model of the gas condensate field in the depletion mode ($\beta(t) = 1$).

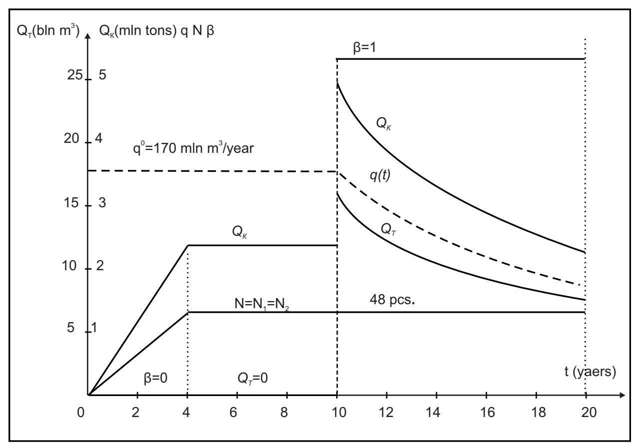

Figure 4: Main parameter dynamics of the development model of the gas condensate field with a complete cyclic process in the first 10 years ($\beta(t) = 0$) and in the depletion mode in subsequent years ($\beta(t) = 1$).

3 Numerical calculations of a gas condensate field development model

This section describes two numerical experiments using the example of one conditional gas condensate field with a planning period of 20 years. Figures 3 and 4 show the main parameters of the gas condensate field's development dynamics.

We choose the following initial parameters for the gas condensate field: $V^0 = 420$ billion m^3; $p^0 = 32$ MPa; $q^0 = q_N = 170$ million m^3/year; $N_1(0) = N_2(0) = 0$.

According to the formula (29) in the calculations, it is assumed a piston displacement of fatty gas by dried gas.

In two numerical experiments, we use the same borehole increment dynamics. The borehole increment is carried out in the first 4 years by 12 pieces per year for each type of boreholes. The experiments differ only in the control parameter $\beta(t)$ (a fraction of injection wells used as extraction wells).

In the first experiment, the control $\beta(t)$ equals 1 for the entire planning period. We are developing the field in depletion mode. Economically, such a regime is unjustified since it is not rational to use more expensive injection wells as extraction wells over the entire planning period. However, the possibility of a model implementation of this mode is of interest.

In the second experiment, the complete cycling process ($\beta(t) = 0$) is carried out at the deposit over the first 10 years. In this case, all produced gas is dried and immediately injected into the formation. Furthermore, the field is developed in the depletion mode ($\beta(t) = 1$) in the remaining 10 years.

Let us analyze the first numerical experiment. A decrease in hydrocarbon reserves occurs during a gas condensate field development. With their decrease, the reservoir pressure drops, and the borehole flow rate decreases.

In the first 4 years, the industrial production of gas and condensate is increasing. The increase is due to the commissioning of a significant number of new wells. Production on them exceeds the decrease in flow rate and a decrease in the condensate fraction in the fatty gas.

Over the next 16 years, the number of wells remains constant, and marketable gas and condensate production drop. Simultaneously, a reduction in condensate production is more substantial than a decrease in gas production. Reducing the potential content of condensate in reservoir gas provides the observed effect. If we considered the breakthrough of dried gas to the wells, the decline in condensate production would be even more significant.

As a result, the total gas production over 20 years is 210 billion cubic meters. The total condensate production for the same period is 47.6 million tons.

Let us analyze the second numerical experiment. A complete cyclical process is observed during the first 10 years. In this case, commodity gas production is equal to zero. It means that all produced and dried gas is pumped into the reservoir. At the same time, recoverable gas reserves in the reservoir remain unchanged.

During the first 4 years, condensate and fatty gas production increased linearly due to the uniform input of new wells, constant reservoir pressure, and the piston method of displacing fat gas from the reservoir with dry gas. For the next 6 years, we have not commissioned new wells. Reservoir pressure remains at a constant level. Therefore, the production of condensate and fatty gas is unchanged.

At the 10th year-end of field development, its regime instantaneously changes from a complete cycling process to a field development in depletion mode. In this case, the production of commercial gas and condensate increases dramatically. It is due to a sharp increase in the number of wells operating for extraction. In the future, over time, production will fall.

As a result, the total gas production over 20 years is 137 billion cubic meters. The total condensate production for the same period is 55.3 million tons.

4 Conclusion

This article has built an aggregated continuous dynamic model of the gas condensate field development using a cycling process. The essence of this process is to pump dry gas into the formation to reduce the drop in reservoir pressure. Starting from a low reservoir pressure, the gaseous state of the wet gas contains more condensate at higher pressure. This fact makes it possible to extract more condensate from the formation.

The advantages and disadvantages of the results obtained are visible in the experiments under consideration. Therefore, it is necessary to conduct a more detailed numerical and analytical study of this model, considering optimal control theory. However, this is a topic for another article.

Conflict of interest: The author states no conflict of interest.

Data availability statement: The author can confirm that all data used in this article can be published in Open Computer Science.

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