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# IMPROVEMENT OF TECHNOLOGICAL-MATHEMATICAL MODEL FOR THE MEDIUM-TERM PREDICTION OF THE WORK OF A GAS CONDENSATE FIELD

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***Запропоновано аналітичні та алгоритмічні доповнення до математичної моделі прогнозу роботи газоконденсатного родовища в газовому режимі. Вдосконалено методику розрахунків прогнозів основних газодинамічних параметрів та показників розробки продуктивних покладів. Для перевірки нової моделі використовувались фактичні дані родовищ України. Створена програмна реалізація розробленої технолого-математичної моделі впроваджена та апробована в газовидобувному виробництві***

***Ключові слова: газоконденсатне родовище, інтенсифікація припливу, видобуток вуглеводнів, показники розробки родовища, газодинамічний розрахунок***

***Предложены аналитические и алгоритмические дополнения к математической модели прогноза работы газоконденсатного месторождения в газовом режиме. Усовершенствована методика расчетов прогнозов основных газодинамических параметров продуктивных залежей. Для проверки новой модели использовались данные месторождений Украины. Созданная программная реализация разработанной технолого-математической модели внедрена и апробирована в газодобывающем производстве***

***Ключевые слова: газоконденсатное месторождение, интенсификация притока, добыча углеводородов, показатели разработки месторождения, газодинамический расчет***

## 1. Introduction

Predicting the gas condensate fields in the gas regime is one of the most important applications of mathematical modeling in the oil and gas sector [1]. This is connected, on the one hand, to the growing need for ergonomic gaseous fuel – natural gas – in the markets for natural resources. From the other hand, the gas regime in particular is the most common in the course of standard development of gas-condensate fields at depths accessible by contemporary wells [2].

The technological innovations of downhole gas production [3] undoubtedly require improvement in mathematical and software provision. In particular, it has always been important to predict gas production for a half century based on the classic gas laws, laws of conservation, motion and balance of substances in the underground layer-reservoir [4]. In the field of mathematical modeling of underground reservoirs, scientific paper [5] addresses many issues, as well as the detailed practical guidelines [6]. In particular, article [6] demonstrates contemporary methods of mathematical modeling of the work of underground reservoirs.

For the short-term mathematical modeling of separate wells, the methods that are based on one of two principles are used: modeling the work of a field using the method of finite elements [6] and the method for compiling material balance of a gas field [1–3].

The problems, connected with the plecement of wells, geometric configuration of the well bottom, which may change after capital repairs and additional exploration of the field, require more detailed technological-mathematical modeling, optimization of arrangement of the points or horizontal lines of the well bottom [7], account of inaccuracy in geological models [8], multilayer development [9]. This extended multifaceted problematics requires further examination with the application of comprehensive technological-mathematical modeling. When the joint gas-dynamic prediction of parameters of development of geometrically complex gas-condensate reservoir and multi-row multi-bottom wells over the short term is necessary, they pass to the multistage program study by special working groups. For developing each gas field, it is necessary to create a separate project of development and industrial operation, which contains geological-technological model, mechanical-technological model of wells, geological-field model of the bottom portion of the well, mechanical-technological model of wellhead equipment.

If the prediction over the medium-term period (5–10 years) is necessary for the fields, which are at the final stage of operation, it is possible to abandon a number of expensive design and scientific research in favor of accurate gas-dynamic modeling of reservoirs and wells according to the material balance method. If it is necessary to use comprehensive software program packages or operational-engineering programs, they pass to original software-mathematical designs of the comprehensive-systems type.

That is why it appears relevant to study the totality of gas-dynamic processes in the extractive exploration based on applying the methods of material-energy balances and using mathematical and integration software tools.

## 2. Literature review and problem statement

At present, modeling the work of a field is one of the contemporary technologies, applied in the development of productive zones and gas production, in the assessment of recoverable reserves. It is used for the comparison of different mechanisms of production, providing for a base of economic analysis of the potential scenarios of the field's work. The forecasts of mode parameters of gas-condensate fields obtained on this technological-mathematical base are exceptionally important for business planning in the gas extracting companies.

In practice, accurate medium-term prediction of parameters of development of gas-condensate fields proves difficult. Such prediction must consider a large number of special features and limitations of the technologies, planned to be applied, with a short and medium periods of implementation-realization. One of the simple but expensive methods to solve the questions and problems of such prediction is the acquisition of the software and hardware complexes from Halliburton and Schlumberger companies or their complexes-analogs. But when technological peculiarities emerge in the gas-extraction production, connected to the innovative methods of production intensification, the research institutes nevertheless prefer programming in the classic mathematical program packages. The existence in the mathematical packages of the integrated environment of development of the program code and computations with the use of scaled and relational databases, the tools of animated visualization, tying to the actual design of wells, is convenient [2, 3, 6, 9, 10].

Using the balance methods of predicting the work of a gas field, engineers have to accept a number of assumptions, which influence accuracy of the final result. Carrying out the analysis, it is possible to solve the problems, connected with the control over field development, to compare the design indices of development to actual data, to predict the production of gas and condensate, to track the most significant factors that influence the deviation of the planned and actual indicators of the field development [8].

Taking into account the complexity of geometry of the productive horizons, the ambiguity in interpretation of results of geophysical research into characteristics of the well bottom zone, as well as the change of these indices over time, the verification and estimation of relevance of these assumptions is possible only by way of retrospective analysis. This leads to the fact that a large number of variables that change over time are introduced into the model in the form of constant values, the result of which is the growing inaccuracy in the calculations: in addition to possible initial error, there appears the accumulated error [11]. Such factors do not make it possible to conduct precise estimation of the projected corrections of regime parameters of the field performance, which is especially important before conducting the intensification of gas inflow (with the injection of dry gas or using the exhaustion regime [12]), when it is not possible, or undesirable, to stop wells for a long period for examining their work.

The described below mathematical and conceptual computer model with logical continuation of the ideas from [6, 8, 11–13, 15] partially solves similar problems owing to the creation of the new algorithm of calculation using the base of initial variables and their dynamic correction in the process of calculation. The correction of the key set of the gas-dynamic parameters made it possible to considerably increase the accuracy in predicting performance of gas fields. Here it is important to note the adaptive flexibility of the technological-mathematical model proposed not only to the averaged regime parameters of reservoir and physical-chemical properties of gases, but also to different technologies of the intensification used. Successful approaches to the solution of such a flexible program configuration are possible to find in the full integrated licensed packages Eclipse Petrel [13], but the speed of modeling of the complete cycle of calculations is low due to the complicated interface and manual handling of the program's parameters. Furthermore, authors of the scientific papers [13, 15] failed to simulate in such a set of programs the operation of a two-row well or half thermally insulated column of PCP.

The technological peculiarities of intensification of the field's work require a more detailed account of regime parameters separately on the bottom and wellhead, change in the function of distribution of pressure and temperature not only along the layer, but also the column of a well. The coefficient of thermal conductivity from the water-bearing rocks to the flow of gas also influences the field's work to a large extent. The approach to solving the problem from the side of application of a separate program ANSIS (individual thermohydraulic calculation of a well) [14] and the subsequent iterative step by step calculations of flows and balances in the layers and wells – obtaining a significant error of prediction for the period longer than 5 years [15]. The programs of thermal simulation (similar or the analogs of the program ANSIS) or hydraulic modeling (similar or the analogs of the program WellPress) perform excellently, when used separately, but the transfer and copying of data to Eclipse Petrel or another analogous predicting program take too long.

In each of the software-simulating systems – prototypes to the designed system – we found different shortcomings in the course of the represented studies, since such specialized designs solved highly specialized tasks or did not consider a number of important initial data. The classic examples of such software products – ArcGIS, DV-SeisGeo – are explored in [16]. They are very relevant and necessary for the solution of particular production-geological problems, but the modeling of gas-dynamic processes exceeds the scope of functionality.

Rather high accuracy was demonstrated by the calculations of comprehensive problems using the programs CGasFlow, GasConDebit, WellPress, GasPro. The application of a set of such simplified programs of gas-dynamic and hydraulic simulation makes it possible to solve with engineering accuracy a fairly wide circle of issues when predicting gas-condensate fields. While comparing results of using the enumerated list of applied programs with the actual parameters of the verified fields, it was necessary after all to use several programs simultaneously, and then to connect the entire chain of predicting calculations all together. If only the medium-term forecast of the field's work is necessary, and the short term one is not relevant yet, then the time losses to the conceptual and preliminary engineering calculations are not acceptable.

And finally, the important component in the practice of taking account by the empirical dependencies of crystallization of chemical substances in the geological productive rocks [17] that is forgotten even by large corporations – developers of the appropriate specialized software. Authors of the present work propose to add the necessary formula of correction of viscosity and compressibility of the obtained gaseous fluids. In their opinion, this not only successfully complements the analytics of determining the long-term calculations of the predicting parameters [18], improving the accuracy of results of the medium-term forecasts of production, but it will lead to essential saving of fuel-energy resources as a whole [19].

Actually, in each particular case of developing or application of the software and hardware systems, specialized program products with the built-in mathematical model, the purpose must justify investments for the detailing of programming and testing of the adequacy of modeling the basic physical and physical-chemical processes [2–4, 9].

The combination of the growing relevance of specialized scientific-engineering tasks on the base of contemporary technologies of intensification [20], simulation of new geological [21] and hydrodynamic [22] specificity, development of the comprehensive programs of intensification of production at a late stage of operation of the gas-condensate fields [23], training-practical methodologies of prediction under conditions of contemporary technologies of the development of fields [2, 4, 18, 22] became the main stimulus for the development of improved specialized technological-mathematical model and its program realization. One of the relevant technological tasks of well control, for an example, energy-saving technologies, is the control over immersion and surface pumps and compressors based on the monitoring and predicting the regime parameters [26].

Thus, the combination of specialized scientific-engineering problems of the prediction of gas production and required by the account of possible innovation-technological intensification in the production of hydrocarbons leads to the need of creating a more universal mathematical model of the work of a gas field. Essential steps are taken in this aspect by the represented papers [24, 25]. But while [24] paid more attention to modeling the layer systems in dynamics, then [25] presents more accurate simulation of wells. An attempt at partial combination of positive results of the mentioned scientific trends into the uniform modeling space gave birth to a number of new functional properties. Important new property is the possibility to conduct rapid accurate correct calculations of the regime parameters from the reservoir to the comprehensive gas treatment unit (CGTU). This property must be included by its analytics into the temporal-spatial calculations of the predicting indices of the work of gas-condensate fields. Inclusion and full parametric integration of the more accurate gas-dynamic model layer-well – CGTU with a general mathematical model of temporal-spatial prediction will draw nearer the creation of the maximum-convenient integrated software-analytical environment of predicting the work of gas-condensate fields. Authors made an attempt at its creation and maximum adaptation for the operating fields in the application to the medium-term forecasts for the period of development of gas-condensate fields of up to 10 years.

## 3. Aim and tasks of the study

The purpose of the work is the modification and verification of the mathematical model of gas inflow and its lifting by the well taking into account a change in viscosity, gas compressibility, heat exchange processes of the system "gas-layer-column PCP" along the way of its motion, integrated into a general updated technological-mathematical model of gas-condensate production.

To accomplish the aim, the following main tasks were set:

– to develop and verify the improved particular mathematical models of gas inflow to the well bottom and its lifting on the example of parametric history of the main indices of development of real fields, history of the regime parameters of the operating wells;

– to integrate proposed applied empirical formulas and the computational-algorithmic techniques (logic-algorithmic bonds) for the standard applications of reservoir-engineering for the medium-term period;

– to develop the program realization of the improved general technological-mathematical model of development of gas-condensate field, which maximally adequately (by the actual history of the indices of development of test fields) describes the medium-term predictions of the main regime-technological parameters;

– to carry out verification of the program realization of the mathematical model in the operating field under conditions of specific measures for intensification of the well production.

## 4. Description of peculiarities of mathematical and algorithmic model

A general mathematical model of development of a gas field is based on the system of equations that describe the plane-radial inflow of gas to the well and vertical transport of gas along the pump and compressor pipes. The use of the equation of material balance provides for the continuity of calculation [1, 2, 7].

In the development of mathematical model, we used the following equations:

– equation of material balance of productive reservoir;

– equation of gas inflow to the well bottom;

– equation of gas transport by the lifting column of pump and compressor pipes (Adamov equation);

– equation of classic calculation and refinement of the filtration hydrodynamic coefficients of the layer;

– equation of refinement of dynamic viscosity of gas in the layer and the PCP column;

– equation of refinement of the coefficient of gas compressibility in the layer and the PCP column;

– equation of refinement of the coefficient of hydraulic resistance;

– the modified Adamov equation with the correction for nonisothermic lifting by the PCP column.

The special feature of mathematical model is taking account of chronological change in molar mass of the mixture in the modified nonisothermic Adamov equation [15] and the Starling-Ellington equation of viscosity.

A general form of the applied function of dynamic viscosity μ(P, T, M) of Starling-Ellington should be demonstrated in more detail: it is substantially dependent not only on pressure and temperature in the layer but also on actual molar mass of the mixture:

$$\mu(P,T,M)=1\frac{(9.41+0.02\cdot M)\cdot(1.8\cdot T)^{1.5}}{(209+19\cdot M+1.8\cdot T)\cdot 10^{7}}\times$$
$$\times \mathrm{EXP}\left(\left(3.5+\frac{547.8}{1.8\cdot T}+0.01\cdot M\right)\times\right.$$
$$\left.\times\left(\frac{P\cdot 10^{3}}{\mathrm{Zskv}(P,T)\cdot\frac{8314.3}{M}\cdot T}\right)^{\left(2.4-0.2\left(3.5+1\frac{547.8}{1.8T}+0.01\cdot M\right)\right)}\right), \tag{1}$$

where μ is the dynamic viscosity; P is the mean pressure; T is the mean temperature; M is the molar mass of the mixture; $P_{nk}$, $T_{nk}$ are the pseudo critical pressure and temperature of gas; Zskv is the coefficient of gas compressibility (function from pressure and temperature).

It is evident from equation (1) that the formation of condensate in the layer and corresponding decrease in molar mass requires the correction of viscosity, which is included in the classic formula of calculation of linear coefficient of hydrodynamic resistance of productive layer at the plane-radial filtration $A_f$:

$$A_f=$$
$$=\frac{\mathrm{Zskv}\left[\left(P_{pl}+\frac{P_1^2}{P_1+P_2}\right),T\right]\cdot\mu\left[\left(P_{pl}+\frac{P_1^2}{P_1+P_2}\right),T,M\right]\cdot P_{at}\cdot T}{\pi\cdot k\cdot h\cdot T_{at}}\times$$
$$\times\ln\left(\frac{R_k}{R_c}\right), \tag{2}$$

where μ is the dynamic viscosity (function from three parameters); $P_{at}$, $T_{at}$ are the atmospheric pressure and temperature; $P_{pl}$, $P_1$, $P_2$ are the layer, bottom and well head pressures; k is the permeability of layer; h is the bulk of layer; $R_k$ is the radius of power circuit; $R_c$ is the radius of well at the bottom.

One can see two parameters in equation (2), which need correction at each step of calculations: dynamic viscosity and gas compressibility coefficient. When calculating the compressibility coefficient Zskv, Authors suggest introduction into the calculation formula of the Platonov-Gurevitch approximation that has the form:

$$\mathrm{Zskv}(P,T)=\frac{0.1\cdot P}{P_{nk}}+\left[0.4\times\log\left(\frac{T}{T_{nk}}\right)+0.73\right]^{\frac{P}{P_{nk}}}. \tag{3}$$

At the calculated step, we take not the layer pressure but the mean dynamic pressure P between the starting value P1 and the final P2 in the productive zone along the axis of filtration in the following form:

$$P=\frac{2}{3}\left(P_1+\frac{P_2^2}{P_1+P_2}\right). \tag{4}$$

Formula (4) is successfully applied in the practice of pipeline hydraulics, and, based on the hydraulic analogies at the distribution of pressures along the axis of the flow; this particular refining analytical construction is selected. In formula (2), one may see an example of application (4) for averaging the pressure in the section of the inflow between the layer pressure $P_{pl}$ and the pressure on the bottom of the well $P_1$. The latter novation made it possible to conduct additional correction of the parameters at each step.

The algorithmic construction of technological-mathematical model is in detail represented by Authors in [11], and the previous mathematical modification of the system of equations of nonisothermic lifting by the inclined well – in [15]. Let us consider the conceptual-computer part of modeling in more detail. Hierarchically, computer model consists of three main building blocks: regulating unit, the block of constructing the base of initial data and the calculation nucleus of the program (Fig. 1).

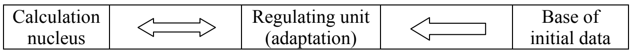


Fig. 1. Conceptual block diagram of the proposed computer technological-mathematical model of development of a gas-condensate field

The base of initial data (Fig. 1) is automatically formed after the line-by-line (for each well or a group of wells) introduction of the first layer of initial variables and point indication of the possible projected corrections, namely:

– the drained gas reserves; the gas, obtained prior to the beginning of calculation; the starting layer pressure;

– layer temperature; the mean temperature gradient; the component composition of gas;

– depth to the middle of the interval of perforation; PCP diameter; coefficients of filtration resistances A and B;

– the maximum permissible debit; the maximum permissible depression to the layer;

– the minimally permissible operating pressure (minimally permissible pressure on the well head);

– PCP roughness coefficient, well-performance coefficient.

As a result of the block's work, a three-dimensional matrix is formed, where initial data for the calculation of the j-th month are represented in each horizontal layer, and in the vertical – of the i-th well (a group of wells). Initial data of each well (a group of wells) are recorded in the line with the index i,j.

Regulating unit (Fig. 1) is responsible for the readout and line-by-line introduction of initial data from the formed base to the calculation nucleus of the program, closing the calculation on the equation of material balance, correction of initial data for each layer, according to the calculated current indices, and formation of the resulting tables. The regulating and adaptation blocks jointly complement the classic algorithmic nucleus, described in the scientific literature [1, 13, 16].

In the calculation nucleus (Fig. 1) we perform initial data processing for each well (a group of wells), that are supplied from the regulating unit, and the five-stage calculation of necessary indices:

– at the first stage of calculation, the automated selection of regime (constant debit, constant depression to the layer, constant operating pressure) is conducted;

– at the second stage, the current layer pressure is specified;

– at the third stage, coefficients for calculating the vertical transport (at the unknown debit) are determined;

– at the fourth and fifth stages, by the iteration technique we determine the inflow of gas, depression to the layer and operating pressure on the well head, as well as the refinement of variables in the Adamov equation (at the known debit).

On finishing the work of calculation nucleus, the following indices return to the regulating unit: debit, depression to the layer, the well bottom pressure, operating pressure on the well head, static pressure on the well head, the refined value of layer pressure, the coefficient of PCP hydraulic resistance, the number of the applied mode of calculation.

After performing the calculations, the regulating unit forms i+1 tables with the predicting indicators of the work on the field as a whole and for each i-th well (a group of wells) separately.

## 4. Correction of current initial data

As was noted above, mathematical model automatically corrects certain initial data, calculating the correction coefficients or recalculating the variable completely. As the first example we examine coefficient of hydraulic resistance of the pump and compressor pipes (CHRPCP). At the first stages of constructing the model, CHRPCP was considered as the constant magnitude or was calculated once. In the process of designing an algorithm for performing the calculation according to the Adamov formula, we made a decision to perform its recalculation for each well (a group of wells at each layer of the work of model. An example of the result of this recalculation is represented in Fig. 2. Graphic dependencies are built by the results of the program realization of mathematical model in the Matlab software.

Correct determining the coefficients of filtration resistance $A_f$ and $B_f$ of the quadratic binomial equation of filtration, applied in the proposed model in the classic form of equation of gas inflow with debit Q to the bottom of the well [3, 4, 5, 18]

$$P_{pl}^{2} - P_{1}^{2} = A_{f} \cdot Q + B_{f} \cdot Q^{2}, \qquad (5)$$

where $P_{pl}$ and $P_1$ are the layer pressure and pressure on the well bottom, also important for conducting accurate predicting calculation. These coefficients describe the geometry of inflow, the physical properties of fluid and filtration characteristics of the layer. It is obvious that to tell that their values are constant and do not change over time is also impossible. To accurately determine some variables, which are part of these coefficients, is fairly problematic (it is difficult to control a change over time in the real radius of well or zone of drainage). The need for conducting correction by viscosity (1), (2) and coefficient of gas compressibility in the layer (3) is obvious, since they significantly influence the final result. Fig. 3 demonstrates the example of dependency of the coefficient of gas compressibility on the layer pressure, obtained when applying equation (3) for different values of layer pressure.

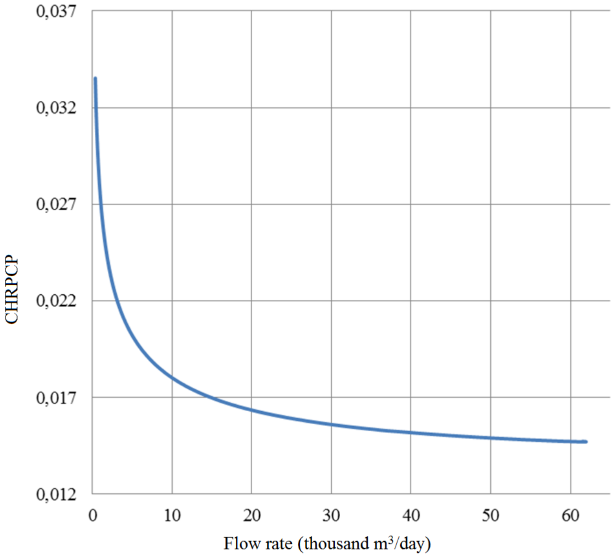


Fig. 2. Example of the CHRPCP dependency on the well's debit

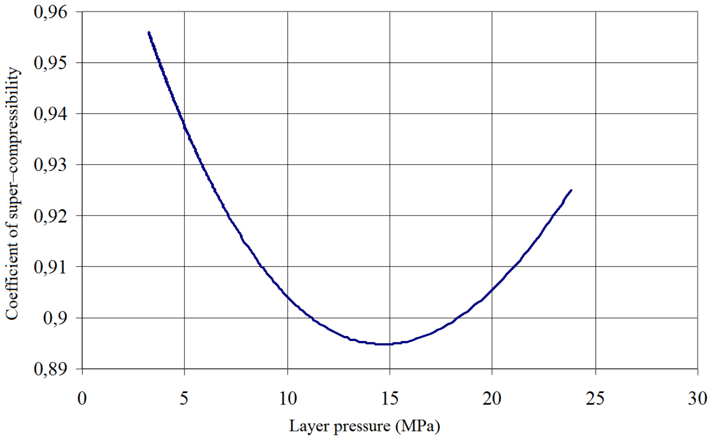


Fig. 3. Example of dependency of coefficient of gas compressibility on the layer pressure

Also analogous is the implemented procedure of correction of coefficients of the filtration resistance of PCP column by multiplication by the correction coefficients (during each contact with the calculation nucleus according to the principle of the escalating multiplication):

$$\lambda_{new} = \lambda_{prev.step} \cdot K_{cor}, \qquad (6)$$

where $\lambda_{new}$ is the new value of coefficient of hydraulic resistance of the PCP column; $\lambda_{prev.step}$ is the value of coefficient of hydraulic resistance of the PCP column at the preceding step of calculation; $K_{cor}$ is the correction coefficient.

The correction coefficients for the coefficient of filtration resistance of the PCP column PCP also depend at each step of temporal layer on the calculated viscosity (1) and coefficient of gas compressibility (3).

## 5. Example of application of the model

The predicting calculation of parameters of development according to the initial data about the object of one of the fields of Poltava Region, Ukraine was taken as an example. The calculation was carried out by three variants:

1 – using the classic technique without connecting to the correction modules [18];

2 – with regard to the correction of initial data base relative to the current indices of calculation;

3 – analogous to the second variant but taking account of conducting intensification by comprehensive hydrogen thermobarochemical action on the well bottom zone [20], designed for the 25–27th months of the field operation relative to the start of calculation.

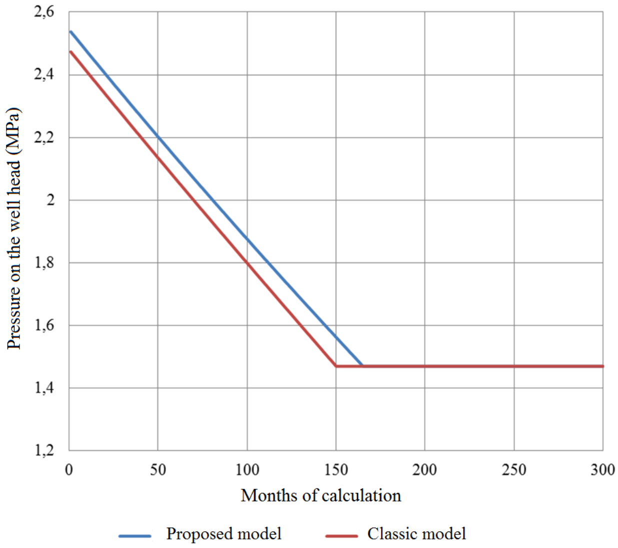


Fig. 4. Predicting operating pressure on the well head according to the first and second variants of calculation

Predicting indices by the first variant coincided fully with the results, obtained in the design organization: it is expected that the work of the field must be executed in the regime of constant depression to the layer with the transfer into the mode of constant operating pressure in 158 months of operation after the start of calculation. The second variant shows similar results, but the dynamics of indices somewhat differs. The most essential difference is the fact that the transfer into the mode of constant operating pressure must be executed somewhat later – in the 167-th month from the start of calculation (Fig. 4).

There are also differences in the dynamics of gas extraction (Fig. 5). The difference in the layer pressure (Fig. 7) according to the variants of calculation is due to the difference in the volumes of gas extraction.

The third variant of calculation involves performing the work on intensification. Using technique [11], we performed calculation of the new coefficient of permeability, and, accordingly, the new value of filtration resistance $A_f$. Since the intensification of inflow will be carried out not simultaneously in all wells of the rerservoir, but in series in the course of three months, for the accuracy of calculation the one group of wells is divided into 3 parts (one well in each new group), but the initial calculation data are introduced into the base separately, according to the calendar plan of performing the work on intensification (Fig. 6).

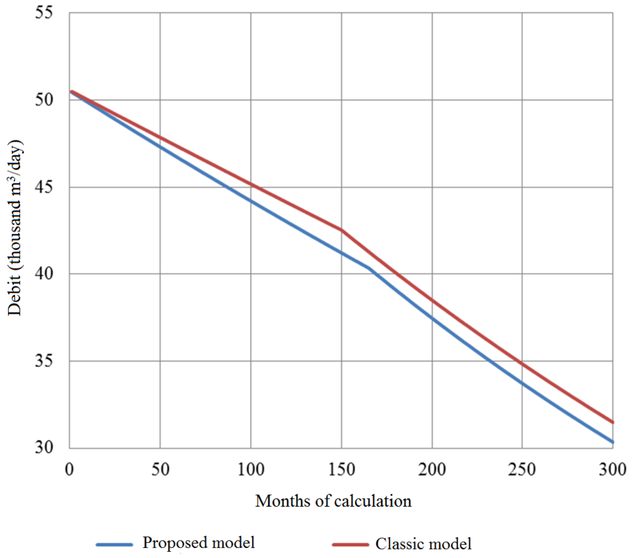


Fig. 5. Dynamics of change in the debit according to the variants

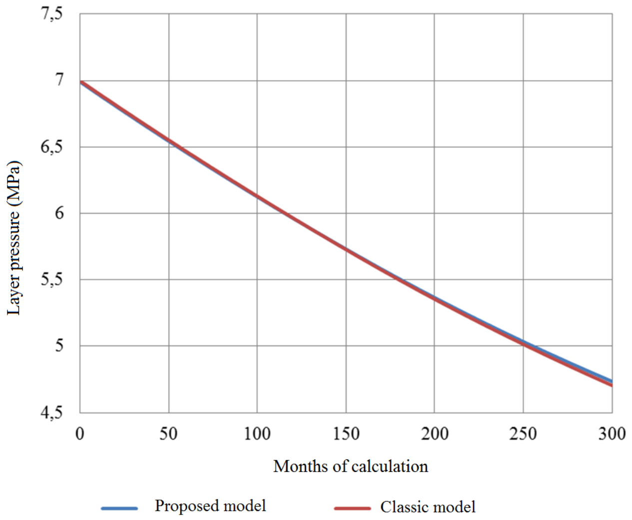


Fig. 6. Changing the layer pressure by the first and second variants

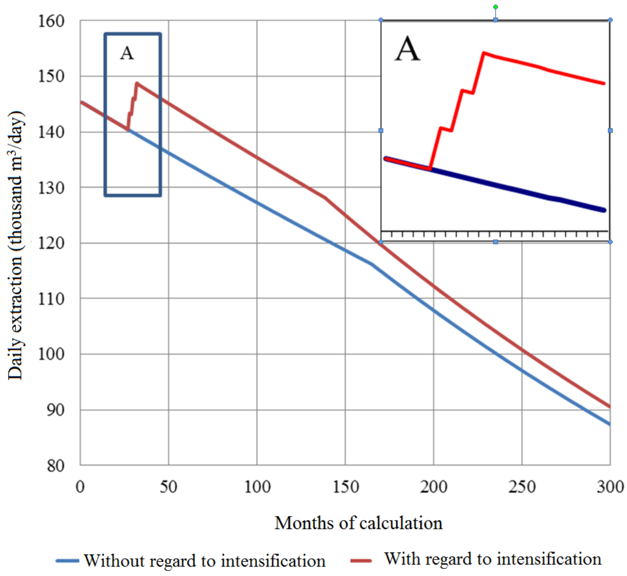


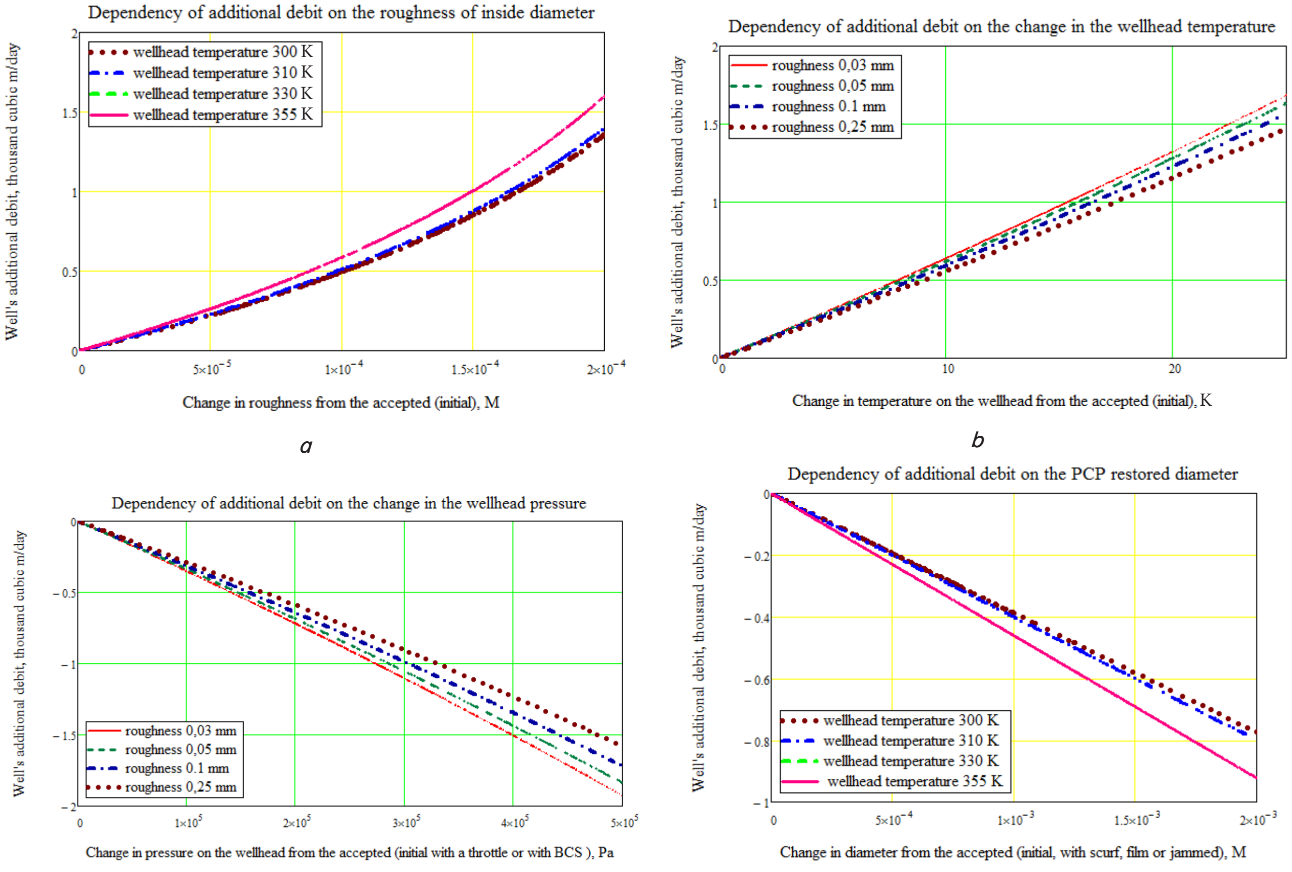
Fig. 7. Daily gas extraction from the field

Fig. 7 displays calculated dependencies of daily gas extraction from the field taking into account and without taking into account of the work on intensification of the inflows. After introducing the appropriate changes to initial data, the program automatically adapts the algorithm of calculation for the work with three groups of wells. This action allowed us to more accurately calculate the extraction of gas during the period of performing the work on intensification, which leads to the more precise prediction of economic indices of the work of the field. The parameters of inflow, pressure on the well head, the bottom and other indices of work are calculated separately for each well without using so-called “average well”, which is reflected in the increased part Fig. 7.

## 6. Discussion of results of the study of the modeling experiments and verification of applicability of analytics to different technologies of the intensification of wells

In addition to the block of examining the long-term outlook for gas extraction (Fig. 1–7), important are the studies of instantaneous change in the output when using technologies of the intensification of lifting part and the well bottom.

Fig. 8 demonstrates dependency of change in the debit of well on the change in different design and regime-technological parameters of PCP. The figures display a change in the debit of well at a simultaneous change in two different parameters after conducting measures or measures for the intensification of gas inflow. Fig. 8, *a* shows the result of technological polishing, ceramic coating, coating with smooth films or with lubricant, polyurethane coating. Different applied thermal insulation introduces corrections to the indices of extraction. Fig. 8, *b* shows dependency at the discrete-assigned values of roughness of the PCP internal surface. Fig. 8, *c* analyzes a change in the debit of well with fluctuations of the wellhead pressure, the roughness is taken as discrete by the actual measurements with profilometer. It is known that the wellhead pressure at the finishing stage of development of a gas-condensate field often depends on the regime of operation of booster compressor station (BCS). The jumps in the consumption of gas or in the change of summary extraction continuously change the wellhead pressures. Fig. 8, *d* analyzes the influence of change in the diameter on the low values in the conditions of the discretely set temperature on the wellhead. The introduction of repairing or correction sleeves to PCP, the use of technologies for intensification with the introduction of pipe into pipe, the jammings of columns somewhat change hydraulically equivalent inside diameter of PCP. The latter fact leads to an abrupt change in the debit of well even at insignificant interferences in the the common flow section.



*a* *b*

*c* *d*

Fig. 8. Dependency of gas debit on the geometric and schematic-technological parameters of the PCP column: *a* — dependency of the additional debit of well on the change in roughness of the PCP internal surface (in comparison with the normative) at different temperatures on the wellhead; *b* — dependency of the additional debit of well on the change in temperature on the wellhead (in comparison with the actual average) at different roughness of the PCP internal surface; *c* — dependency of the additional debit of well on the change in pressure on the wellhead (in comparison with the actual average) at different roughness of the PCP internal surface; *d* — dependency of the additional debit of well on the change in the equivalent diameter (in comparison with the actual average) at different temperature on the wellhead

When they conduct innovation repair of the well and relative-operational measures for the intensification of gas extraction, there occurs a sharp jump of the regime parameters, which corresponds to initial data on the edges of the analyzed dependencies (Fig. 8, *a–d*). The jump of parameter of daily gas extraction is observed also in Fig. 7.

Further improvements in the model are planned to conduct in two directions. First, creation and usage of the base of highly specialized calculations for the non-standard cases of development (simultaneous and simultaneous-separate operation of multi-layer reservoirs, taking account of interlayer flows, the work of extraction by the intertube space). Second, to conduct the work for the creation of the real two-or three-dimensional corrected general model of a gas field, that is, to start withdrawal from the principles of complete linearization with a partial transition to the calculation, which considers real geology.

Let us draw some conclusions on the conducted research and analysis of graphs (Fig. 1–8):

– the improvement of the algorithms of general mathematical model of the performance of a gas field made it possible to considerably improve the predicting calculation of the indices of development of gas field at the gas regime (to 10–15 % in the longer term);

– it is demonstrated that the mathematical model automatically adapts the logic scheme of the calculation based on the entered initial data;

– the possibility of a particular well's calculation of the work of reservoir is shown;

– the possibility is shown of taking account of different technologies of intensification of the inflow, in particular, the application of comprehensive hydrogen thermalbarochemical action on the well's bottom zone, given by the example (Fig. 4–7), the application of PCP with the polymeric coatings (decreasing the roughness of pipes), the application of thermal-insulated PCP, reduction in the operating pressure in the wellhead.

The example of comparative calculation of the indices of work of a gas field according to the classic and proposed techniques revealed that taking account of the change over time of the physical properties of gas and parameters of lifting columns makes it possible to increase the accuracy of calculation of debit by 5–15 %.

## 7. Conclusions

1. As a result of this work, it was possible to establish possible changes in predicting the work of a gas-condensate field after introduction of the correction coefficients and analytical dependencies by 5–15 % by the total average annual extraction.

2. We created and fixed the program realization of the improved technological-mathematical model of development of a gas-condensate field. The scientific-applied peculiarities of the formulation of problem of research are taken into account, under conditions of contemporary technologies of intensification of gas inflow.

3. We developed the technique of comprehensive account of change in the physical properties of gas at a drop in the layer pressure and the speed of motion of gas by the PCP column. The results of calculations and comparison with production data testify to a considerable increase in accuracy of prediction as compared to the classic model. The automation of the process of selecting the optimal general mode of operation of productive layers and wells makes it possible to decrease effect of the human factor on the accuracy of prediction of natural gas extraction.

4. The technological-mathematical model provides the possibility to solve the extended circle of the applied problems of operational medium-term prediction of the work of gas-condensate fields with the tenfold savings of means for the software-hardware complexes of the short term prediction.

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