Risks of gas production forecasting, using material balance equations

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Received: 30.05.2017 Accepted: 12.07.2017

Abstract

The risks of forecasting of the main indicators of gas field development using the system of material balance have been estimated. According to the actual data, estimates of the impact of the components of material balance equations , the algorithm as a whole and the accuracy of the input data on the reliability of the gas withdrawal forecasting have been built. It has been shown that the predominant contribution to the variation of forecast indicators is related to the precision of the determination of initial recoverable gas reserves.

Keywords: *algorithm, deposit, forecasting, gas, material balance, risks.*

The system of material balance equations (MBE) is a tool widely used in the tasks of analysis and forecasting of gas fields development. Compared to full-scale hydrodynamic models of a gas field, the amount of input data for creating material balance equations is minimal. Whereas it allows taking into account in the forecasting of some changes in the system of development of the deposit, in particular in the number of wells and conditions of their operation, it gives material balance significant advantages over extrapolation methods, such as Decline Analysis.

For a gas deposit, material balance can be illustrated on Fig. 1. The mass of gas remaining at a certain time in the formation is equal to the difference between its initial reserves and produced gas (upstream gas). The amount of gas in the formation can be determined by thermobaric conditions in the formation and the pore space volume, filled with gas.

A closed mathematical model of the material balance should allow the forecasting of the dynamics of gas extraction from the deposit. To do this, there are three equations:

the material balance equation itself, which links the current formation pressure with the volume of the taken-off gas;

the equation of gas flow in the reservoir, which determines the rate of gas flow to the wells, depending on the formation and bottom-hole pressures;

equation of gas flow in the wellbore, which links the carrying capacity of the lift depending on the bottom-hole and working wellhead pressure.

While formulating the system of material balance equations one must be guided by the following criteria: minimizing the amount of input data, physical consistency, transparency and stability of the numerical algorithm, low software requirements.

Gas formation material balance equation

In a closed gas deposit, the material balance is written using the generalized Mendeleev-Clapeyron law:

$$\frac{p_{st}V_{prod}}{T_{st}z_{st}} = \left(\frac{p_{in}}{z_{in}T_{in}}\right)V_{in} - \left(\frac{p_t}{z_tT_t}\right)V_t\,, \qquad (1)$$

where p_{st}, T_{st} are pressure and temperature for the standard conditions of produced gas metering; V_{prod} is a accumulated volume of produced gas; p_{in}, T_{in} is a initial formation pressure and temperature; z_{in}, z_t, z_{st} are the gas compression coefficient at the initial, current formation conditions and at the standard conditions respectively; p_t, T_t is a current formation pressure and temperature; V_{in}, V_t is a initial and current pore volume, filled with gas.

Formula (1) allows us to predict the average weighted (by pore space volume) formation pressure depending on the volume of the produced gas. The main problem of its practical use is to determine the initial and current pore space volume, filled with gas. The pore space volume, filled with gas is the basis for initial deposits calculating in a volumetric way. Therefore, it can be estimated by the size of gas reserves by inverse calculation, regardless of the way in which the deposits are determined. The accuracy of the assessment will directly correspond to the accuracy of the calculation of gas reserves and the determination of initial formation pressure.

$$\frac{p_t}{z_tT_{in}}\left[V_{in} - \left(We_t - Wp_t\right)\right] = \frac{p_{in}V_{in}}{z_{in}T_{in}} - \frac{p_{st}V_{prod}}{z_{st}T_{st}}\,, \qquad (2)$$

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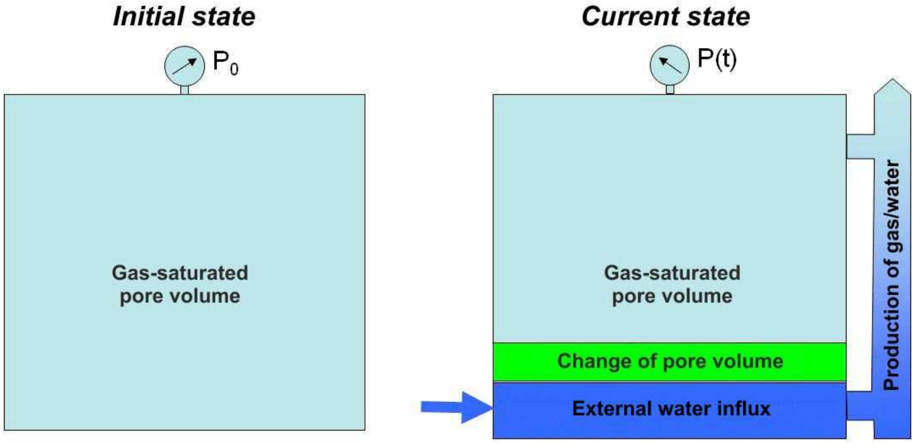

Figure 1 – Gas formation material balance

where We_t is the total volume of water that has invaded the productive part by the time t; Wp_t is the total amount of water extracted by the time t, reduced to formation conditions.

The current pore space volume, filled with gas differs from the initial due to the expansion of the reservoir and associated water with the reduction of formation pressure after the withdrawal of a part of gas reserves, as well as the advancement of water flow during water driving of the wells.

Compressibility coefficients of the reservoir and water are in the order of 10^{-10} Pa^{-1} (of space). It is not difficult to show that in case of their expansion, even at ultrahigh ranges of intrapore pressure reduction, for example, by 50 MPa, the change in pore space won't exceed 1 %, which is compared with the difference in the calculation of the coefficient of gas mixture overcompression by different methods. It won't be a noticeable error even if we pay no regard to the change of pore volume due to retrograde phenomena in gas condensate deposits.

In the presence of a large water-saturated area, which is hydrodynamically connected with the gas-saturated productive volume of the reservoir, the water flows into the formation and completely or partially compensates for the drop in reservoir pressure caused by the selection of liquids and gases through the wells. Accordingly, in the equation of the material balance, the volumes of formation water that have advanced into the formation and raised to the surface should be taken into account.

To calculate the volume of the produced (extracted) water to the formation conditions, the volume factor Bw is used as the ratio of water volume to the formation temperature and pressure, and if necessary, taking into account gas, dissolved in the water to the volume of the same the amount of water measured in the surface conditions. To calculate that, W.D. McCain correlations are often used, which, according to the author, are in good agreement with experimental data at temperatures up to 126 °C and pressures up to 34.5 MPa [1].

The material balance method is not realized in spatial coordinates and requires only a finite-difference approximation along the axis of time. At each time step, by solving the nonlinear equation, one must find the pressure p_t, which satisfies the equation of the material balance in the gas deposit (2). As it is customary in explicit schemes, the values of formation pressure and volume of injected water are used at the next time step to calculate the rate of gas offtake and the rate of injected water flow into the deposit.

The recurring form of the material balance recorded for two time steps, using the category of residual gas reserves $Z(t)$ and the pore space $V_{por}(t)$ occupied by gas at the time t is convenient for use in the prediction algorithm

$$\frac{p(t_{i-1})}{z\left[p(t_{i-1})\right]T_{in}}V_{por}(t_{i-1})=\frac{p_{st}}{z(p_{st})T_{st}}Z(t_{i-1}), \qquad (3)$$

$$\frac{p(t_i)}{z\left[p(t_i)\right]T_{in}}\left[V_{por}(t_{i-1})-\left[\Delta We(t_i)-\Delta W_{prod}(t_i)\right]\right]=$$

$$=\frac{p_{st}}{z(p_{st})T_{st}}\left[Z(t_{i-1})-\Delta V_{prod}(t_i)\right], \qquad (4)$$

where $\Delta V_{prod}(t_i)$, $\Delta W_{prod}(t_i)$, $\Delta We(t_i)$ are the accumulated production of gas and water and accumulated volume of water influx into the deposit over a period of time $\Delta t_i = t_i - t_{i-1}$, correspondingly.

Water influx calculation

To calculate water influx volume into the previously gas-saturated productive part of the formation, many methods have been suggested that differ in both the degree of physical validity and the complexity of the mathematical apparatus. Solving the problem of piezoconductivity under the appropriate boundary conditions, which allow to calculate the rate of water flow due to the action of elastic forces is generally accepted to be considered the exact formulation, which is used for simplified methods comparison.

The analytical solutions brought to the quadrature obtained for cases of infinite and finite strata at constant pressure at the inner boundary of the formation or at constant flow through this boundary for simpler forms of filtration flows are given by A. F. Van Everdingen and W. Hurst (1941) [2]. However, the exact solutions of non-stationary problems of the equation of piezoconductivity are the form of improper integrals from special functions and are not convenient for the organization of numerical procedures. Moreover, for practically useful tasks, it is necessary to determine the flow of water from the field area to the productive part under variable pressure on the gas contour circuit (internal boundary of the aquifer part of the formation). We have Such solutions under the principle of superposition in the form of Duamel integrals. The main problem of algorithmization of the principle of superposition is the need to store in memory all the results of previous calculations, the number of which increases with each subsequent sampling step, so an efficient algorithm for predicting the development of a gas field is based on approximate methods for calculating the progress of water influx in the deposit.

We can significantly simplify the calculation process of volume of water (million cubic meters) that penetrated into the formation for an infinite aquifer region if the average intensity of its flow at each time step Δt_i uses the formula derived from the principle of successive change of the established states:

$$q(t_i)=\frac{2\pi k\,h\left[p_0-p_c(t_i)\right]}{\mu\ln\left(\dfrac{r_c+b\sqrt{\gamma t_i}}{r_c}\right)}\ . \tag{5}$$

By the method of successive change of stable states, a convenient-to-use dependence can be obtained that approximates the exact solution of the piezoconductivity equation for a closed region with sufficient accuracy. Assuming that at each moment of time the pressure distribution in the middle of the region does not depend on the rate of filtration, but is determined only by the form of flow and pressure at the boundary of the formation, then the flow into the well is determined by a formula that is valid for a steady state flow or a semi-steady flow. For a plane-radial flow from an outside bounded impermeable boundary r_a, and inside a circular contact r_c with a gas bearing region, the method leads to the influx formula in the form of:

$$We(t)=\pi h\beta^{*}\left(p_{in}-p_c\right)\left(R_a^2-r_c^2\right)\left[1-\exp\left(-j_w\frac{t}{t_0}\right)\right], \tag{6}$$

where for $t_0=\dfrac{\beta^{*}\mu\,f(r)}{k}$ is a time characteristic; for a semi-steady flow; $f(r)=\dfrac{\left(R_a^2-r_c^2\right)\left[\ln\left(\dfrac{R_a}{r_c}\right)-\dfrac{1}{2}\right]}{2}$ with the dimension of $\left[f(r)\right]=L^2$.

It can be shown that equation (6) completely coincides with the equations used in the Fetkovich method (1971) [3] to calculate the volumes of external water influx to the productive layer. A distinctive feature of the Fetkovich method is the use of the category of weighted average pressure in formula (7) in the material balance and, accordingly, the formulas for determining the productivity index of the influx to the well in the form of

$$j_w=\frac{2\pi k\,h}{\mu\,l\left[\ln\left(\dfrac{R_a}{r_c}\right)-\dfrac{3}{4}\right]}\ . \tag{7}$$

The equations obtained by the method of successive change of stable states, including in the writings of Fetkovich, through the weighted average reservoir pressure in the aquifer region, in their simplicity, well approximate the exact solutions of Van Everdingen and W. Hurst.

The use of the Fetkovich method without significant loss of accuracy let us avoid the necessity of using an algorithmically uncomfortable superposition method in the conditions of pressure change on the internal contour of the aquifer region as a result of gas extraction and proceed to a simple recurrent scheme to calculate water volumes at the next time step:

$$We(t_i)=We(t_{i-1})+We(\Delta t)\ . \tag{8}$$

Then, the Fetkovich equation for calculating the water displacement volume $We(\Delta t)$ – over the period of time Δt з using the weighted average formation pressure in the aquifer region is written as:

$$We(\Delta t)=\frac{Wei}{p_{in}}\left(\bar{p}_t-p_c\right)\left[1-\exp\left(-\frac{j_w p_{in}}{Wei}\Delta t\right)\right]\ . \tag{9}$$

The average pressure in the aquifer region $\bar{p}_t$ is determined by the material balance between the initial elastic water reserves in it We_i and the total amount of water supplied to the productive layer during previous period of time We_t

$$\bar{p}_t=p_{in}\left[1-\frac{We_t}{Wei}\right]. \tag{10}$$

Figure 2 illustrates the possibility of using approximate methods for calculating injected water flow progression on the example of a limited circular hypothetical gas deposit with the ratio of the external and internal contours of the aquifer region of $\dfrac{R_a}{r_c}=5$ with a constant rate of gas withdrawal of 10% per year from the residual stocks. we can consider the results of using the superposition method (SPM Avendinger) to be most accurate, with the response function obtained by Van Everdingen and W. Hurst [2]. Compared to it, the superposition method with the response function (6) obtained by the method of successive change of constants (SPM PSS), and in the recording of Fetkovich (SPM Fetkovich) through the weighted average formation pressure and the corresponding productivity index (7) can be considered to be slightly different from the point the view of practical calculations, both in terms of pressure (P) and volume of water entering the deposit (We). A similar conclusion can be drawn in relation to the simplification of the Fetkovich formula (9), which makes it impossible to use the formulas of superposition (Fetkovich Simple) and to use the recurrent formula (8).

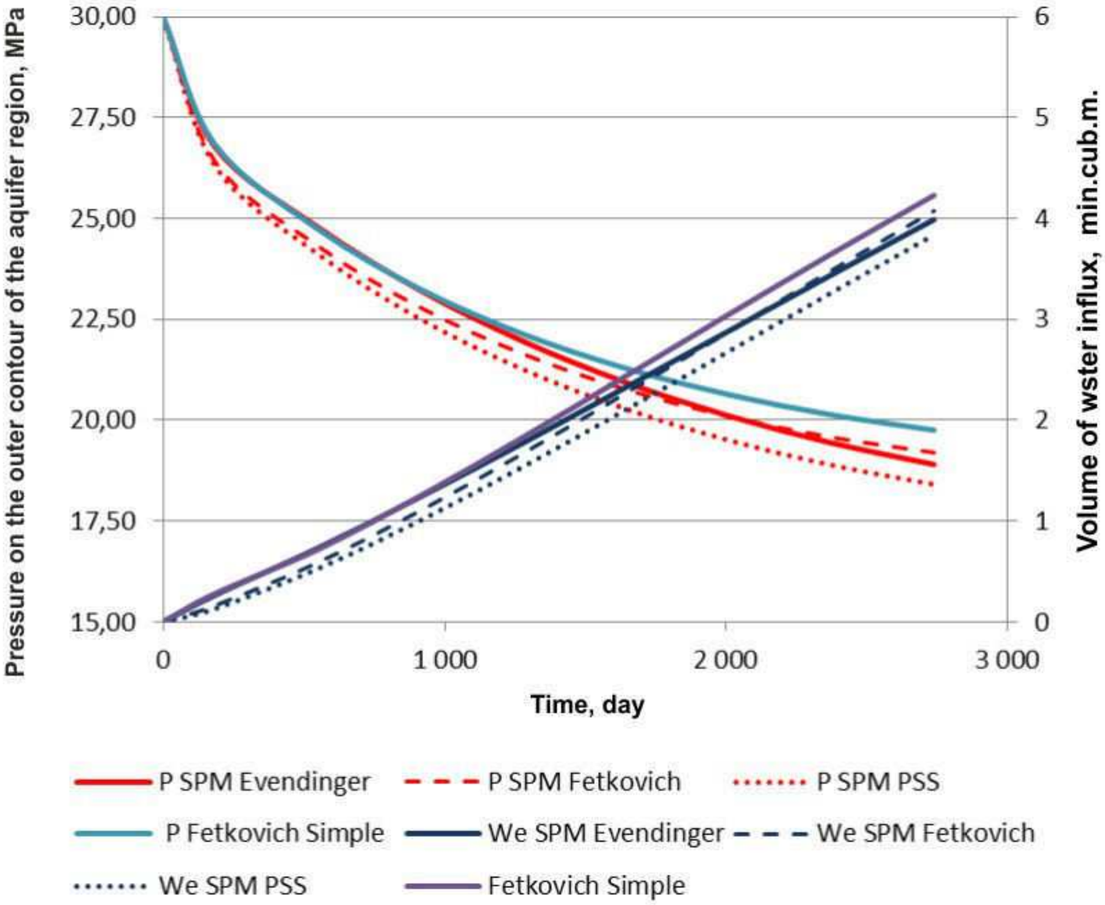

Figure 2 – Comparison of the results of calculation of formation pressure on the outer contour of the aquifer region and the volume of water influx into the productive part

The equation of gas flow to the well bore

As formulas describing the flow of gas to the wells, it is generally accepted to use:

Darcy's law

$$q = K_0 \left[p_c^2 - p_{wb}^2 \right]; \tag{11}$$

Forchheimer's law

$$p_c^2 - p_{wb}^2 = Aq + Bq^2 ; \tag{12}$$

power law

$$q = C \left[p_c^2 - p_{wb}^2 \right]^n , \tag{13}$$

where p_c and p_{wb} are the formation and bottom hole pressure correspondingly; K_0, A, B, C, n are the parameters in the corresponding equations of gas flow to the well.

The first two formulas have theoretical justification, the power formula is empirical, obtained by Rawlins and Schellhard (1935) [4]. The choice of the inflow equation for use in the calculation of the material balance should be based on actual data of wells research in the established modes. The tidal formula should well approximate the actual points of the indicator line without losing the physical essence. Additionally, it should be kept in mind that in the general case an equation with parameters averaged for several wells is used. The chosen equation should lead to a stable calculation scheme. Traditionally, without a special justification it is customary to use the binary formula of the inflow. This formula, with two filtration resistances supports A and B, and has three parameters in its content. Given the vague concept of formation pressure and the complexity of its measurement,its actual value is specified during test results treatment. The formula for the inflow on the basis of the Darcy's law is two-parameter, which essentially simplifies the averaging of the production characteristics of several wells.

The problems of the use of three-parameter formulas can be illustrated by the example of test results processing for well 7 of the Eastern-Poltava gas field (Table 1). Two procedures were used:

"rough", when the usual coefficient of hydraulic resistance (equal to 0.025) was used to calculate bottom hole presssure on the basis of the measured buffer pressure;

"refined" with the definition of the coefficient of hydraulic resistance for each mode, by the equilibrium of bottom hole pressures, calculated by buffer and annular pressure.

The coefficients of the equation of inflow were determined and formation pressure was specified on the basis of the dependence of the bottom hole pressure upon production rate by the least squares method.

Table 1 – Results of established modes testing

Mode	Production rate, thousand m^3 / day	Buffer pressure, MPA	"Rough" bottomhole pressure, MPa	Hydraulic resistance coefficient	"Specified" bottomhole pressure, MPa
1	60	4.90	7.80	0.0581	8.74
2	49	8.37	12.75	0.1294	13.75
3	40	10.79	16.39	0.2056	17.09
4	34	11.77	17.84	0.2453	18.27
5	26	12.45	18.83	0.8148	20.01
1	60	4.90	7.80	0.0581	8.74

Table 2 – Results of the approximation of the indicator line by the binary formula of the inflow

Treatment procedure	A	B	p_c	S_{ad}^2
Rough	0.831	0.095	21.134	459.3
Specified	4.208	0.063	23.501	126.7

Table 3 – Results of the approximation of the indicator line by the inflow formula according to Darcy's law

Treatment procedure	K_0	p_c	S_{ad}^2
Rough	0.104	25.697	570.0
Specified	0.111	24.705	211.6

Table 4 – Results of the approximation of the indicator line by the power formula of the inflow

Treatment procedure	C	N	p_c	S_{ad}^2
Rough	0.0057	1.419	27.60	726.3
Specified	0.0130	1.287	27.78	1715.4

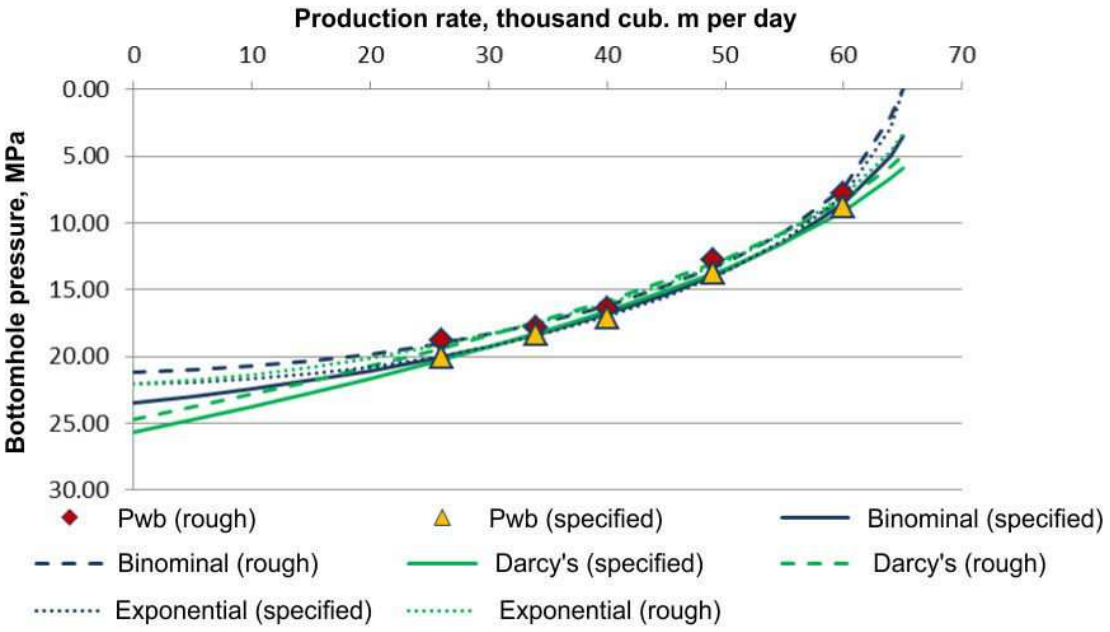

Figure 3 – Aproximation of the results of a well study on the established modes of the inflow formulas

The results of determining the coefficients of the equations of inflow and formation pressure are shown in Tables 2–4 and in Fig. 3.

Attention is drawn to the wide range of reservoir pressure p_c identified on the indicator lines at the value of formation pressure determined by wellhead pressure in a shut in well of 21.99 MPa. All inflow equations are statistically significant as regression equations for the result of hydrodynamic investigations of the indicator line. By the magnitude of the dispersion of adequacy S_{ad}^2, a power function has apparently worse approximation properties. When comparing binary and one-part formulas of the inflow, attention is drawn to the instability of the coefficients of the binomial formula for relatively small changes in the input data. This is a negative quality for its use in the system of equations of the material balance. Therefore, the advantage should be given to the linear equation of flow to the well according to the Darcy law, which is stable when determining the efficiency coefficient and the formation pressure estimation by the results of indicator line approximation. The expediency of using the binary formula of the influx in the system of equations of the material balance should further be based on the results of the processing of hydrodynamic studies of specific wells.

Gas flow equation in the wellbore

To describe the flow of gas in the wellbore the explicit formula by Adamov is often used, which correlates the bending pressure with the mouth pressure and production rate of the well. It is obtained as a result of the approximate integration of the differential equation of isothermal mechanical energy conservation. In the system of SI units it looks as follows [5]:

$$p_{wb}^2 = p_h^2 \exp\left(\frac{0.0683\rho L}{Tz}\right) + \\ +9.9143\cdot 10^3 \lambda \frac{T^2 z^2}{d^5} Q^2 \left[\exp\left(\frac{0.0683\rho L}{Tz}\right) - 1\right], \tag{14}$$

where p_{wb} is a bottomhole pressure; p_h is a wellhead working pressure; L is a well depth; T is a averaged wellbore temperature; Q is a well production rate; z is a averaged over-capacity ratio of gas in the wellbore; λ is a coefficient of hydraulic resistance in the pipes; ρ is a relative gas density; d is a diameter of the lift pipes.

The Adamov formula provides a sufficiently practical calculation point of view. For example, in other conditions, with pressure at the mouth of 4.9 MPa in a well with a depth of 4454 m and a flow rate of 60 thousand m^3 per day, the Adamov's formula should be equal to 8.68 MPa and 8.68 MPa according to the numerical integration of the equation of motion – 8.62 MPa. The difference is less than 1 %.

The most problematic when using the Adamov formula is the substantiation of the resistance coefficient. It is reasonable to assume that in wells equipped with a blunt packer, the calculation of the blow-off pressure through the values of the annular and buffer working pressures should yield the same results. Fig. 4 shows data on the magnitude of the coefficient of hydraulic resistance based on the results of its determination by the difference between the annular and buffer pressure in hydrodynamic studies of 18 wells of several deposits in Ukraine depths from 1200 to 5700 m with a flow rate of 10 to 700 thousand m^3 per day.

Algorithm of development indicators calculation using material balance equation

Algorithm of development indicators calculation using material balance equation is not complicated.

Output data for calculation include:

initial gas reserves;

accumulated extraction and, consequently, residual gas reserves as of the start date of forecasting;

average weighted pressure on the start date of forecasting;

coefficients of filtration resistance or coefficient of productivity for wells or their average weighted values for a group of wells;

formation and average wellhead temperature;

buffer pressure restrictions;

well depth;

diameter of the lift pipes;

properties of gas, sufficient for over-capacity ratio calculating;

assessment of the size of the aquifer area.

The effectiveness of gas production forecasting using the system of material balance equations and the assessment of appropriate risks is illustrated by the example of the first development project of the East-Poltava field.

The depth of wells, often more than 4,500 m, was the main argument when deciding to build a development system by consolidating development objects. As a result, in the first development project, a single system of wells, 3 productive horizons are developed, namely: M1 of the Moscow tier up to 50 m thick and K11 and K12 of the cascade tier with the thickness of up to 20–30 m. The wells exploit the horizons through a common filter with a total length of up to 200 m. Due to the lack of differentiated data on the volume of gas extraction from individual horizons, the possibilities of modern forecasting methods are largely limited. Therefore, the example of the East-Poltava field is indicative for assessing the risks of using the equations of the material balance during the forecasting of development indicators.

When using the material balance method, as with all other simulation methods, the procedure of adapting the model to the development history should be applied. With respect to the system of equations of the material balance, this means that the initial inventory and initial reservoir pressure assumed for simulation for the model at actual gas volumes should ensure consistency between the calculated and actual dynamics of the variation of reservoir pressure in the deposit. Therefore, at the first stage an adaptation of the averaged parameters of the model of material balance was made according to the data of the formation pressure in wells and development indicators for the period of 1995–2008 inclusive.

At the second stage, for the estimation of the confidence intervals for the prediction results and the determination of the contribution of the quality of the input data to them, a stochastic modeling was performed using the Monte Carlo method. For prediction of further dynamics of production and reservoir pressure for all inputs of the material balance, a normal distribution law with the parameters given in Table 5 was adopted.

The third stage consisted in a qualitative assessment of the model based on a comparison of the results of the forecast with the actual indicators of development of 2009–2013, which were deliberately not used at the stage of adaptation of the model.

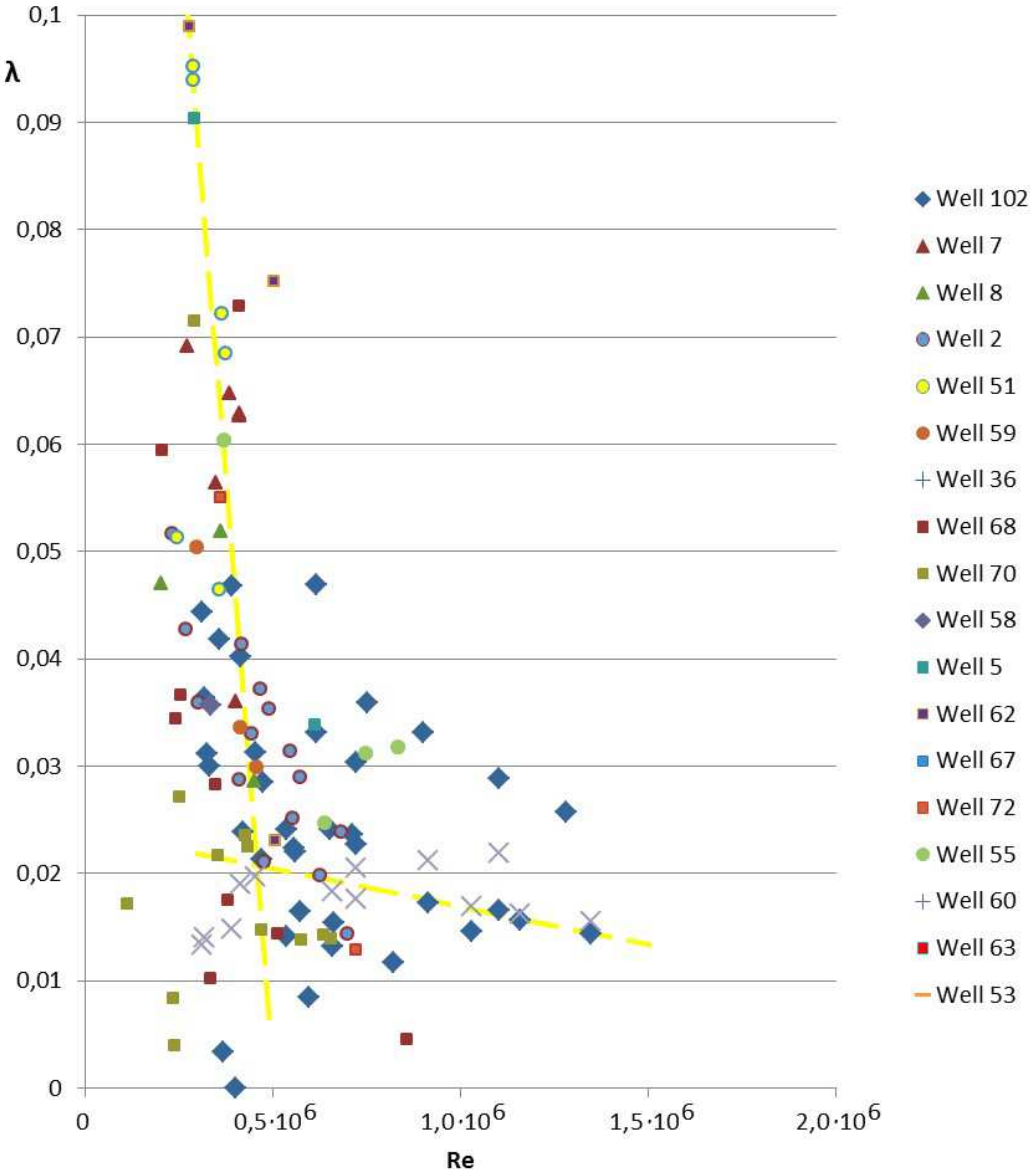

Figure 4 – Distribution of the coefficient of hydraulic resistance between the annular and wellhead pressure

Fig. 5 shows the results of comparison of the forecast average reservoir pressure with its specific measurements in wells. High range values of reservoir pressure measurements associated with the simultaneous drainage of wells of several productive horizons and systematic mistakes of measurements themselves, which does not allow unambiguous determination of the main influential parameter of the material balance – the total drainage of gas reserves. Measurement of reservoir pressure in three wells falls out of the general trend. The most probable reason for the formation pressure measurement technology. Due to the interference of the wells, the depression funnel of the working well lowers the reservoir pressure measured in the adjacent well.

Fig. 5 is an illustration of the fact that the "new" measures of pressure in 2009–2014 are generally in the 80 % confidence interval, which is based on data from 1995–2008. Note that in this interval, there are also new pressure measurements in the well 8, although in the previous period they significantly dropped out of the general trend. The proximity of reservoir pressure to those observed at the beginning of the development of the deposit and their rapid decrease in the new wells 74 and 77 are close, probably indicates that some of the intervals discovered in them were not previously drained due to the lithologic-facial variability of reservoir layers.

Fig. 6 and 7 show the results of forecasting the average rate of wells and annual gas selection with confidence intervals for the first development facility of the East-Poltava field. For the adapted period of development of 1995–2008, the actual data for extraction of the next period 2009–2014 are in the 80 % interval trust prediction. Given that during this period the number of wells on the site increased from 9 to 15, this result can be considered satisfactory.

Tornado chart in Fig. 8 on the example of the annual gas production forecast for 2020 shows that more than 70 % of the variation in the confidence

Table 5 – Input parameters for the Monte Carlo method

Parameter	Unit of measurement	Mathematic forecast	Standard deviation
Depth of formation	m	4500	50
Formation temperature	К	393	3
Initial reserves	million m^3	6200	1000
Initial reservoir pressure	MPa	46	2
Relative gas density	–	0.666	0.04
Potential of the aquifer region	million m^3	500	100
The productivity index of the aquifer region	million m^3 / MPa / day	0.0001	1.00E-04
Working pressure	MPa	5	0.5
Hydraulic resistance coefficient	–	0.178	0.045
Average productivity	thousand m^3 / day / MPa^2	0.050	0.050

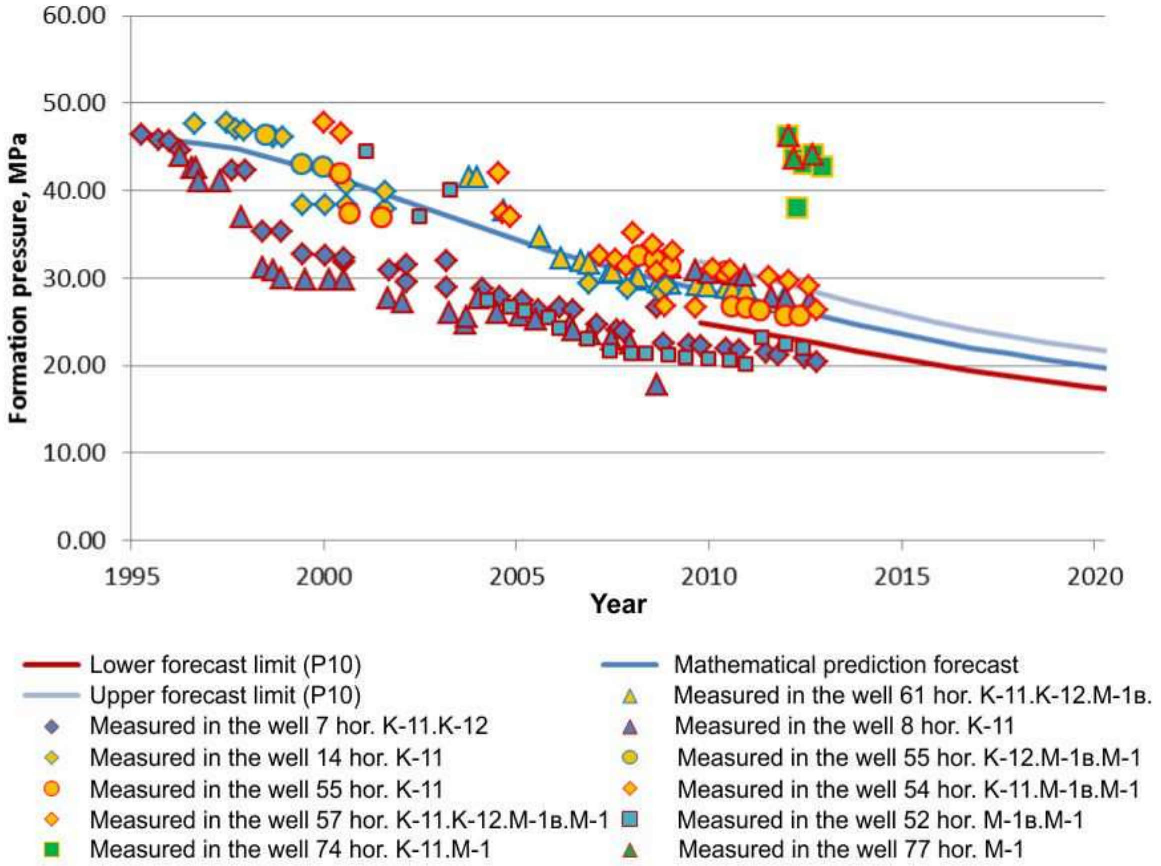

Figure 5 – Results of the forecasting of the average reservoir pressure for the first project of the development of the East-Poltava deposit with reservoir pressure measurements in wells

interval and, accordingly, the forecasting risks associated with the accuracy of the determination of the initial mining gas reserves, the rest almost account for the value of initial formation pressure and the productivity of wells. Given that the initial formation pressure and the coefficient of productivity of the wells are determined with much higher accuracy than the reserves, it is precisely with the definition of the latter that the risk of error is associated with the use for forecasting the system of equations of the material balance. Moreover, the algorithm of the material balance allows us to clarify the gas reserves when adapting the model for reservoir pressure measurements in the wells, avoiding the ambiguous procedure for determining the weighted average reservoir pressure. It is very interesting that the contribution of the least reliablely determined coefficient of filtration resistance in the movement of gas in the lifting pipes is practically not noticeable. This is easily explained by the fact that the loss of pressure on the flow of gas in the formation substantially exceeds its loss of friction in the lifting pipes.

Conclusions

The system of equations of the material balance is a convenient tool for operational analysis and forecasting of the main indicators of gas deposits development. With a small amount of input required for calculating the data, the width of the confidence interval

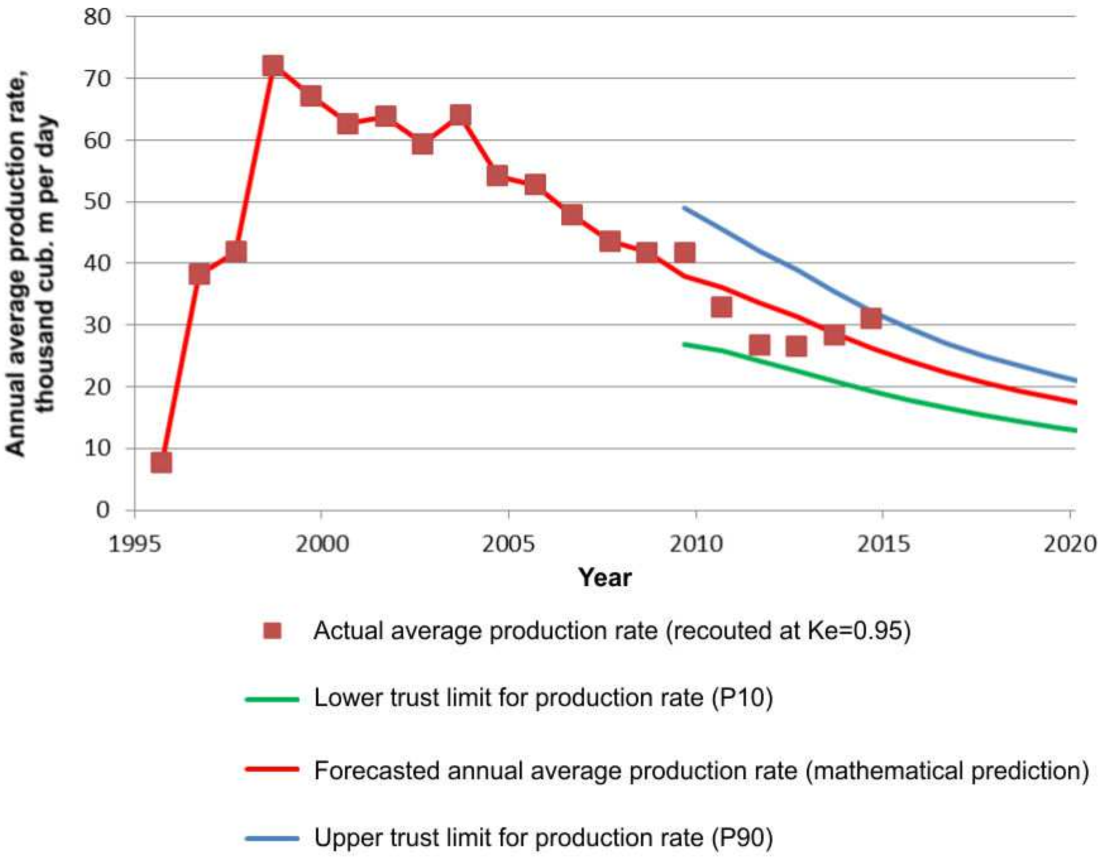

Figure 6 – Results of the annual production rate forecast of the well for the first development facility of the East-Poltava field with reservoir pressure measurements in wells (*Ke* is a coefficient of annual exploitation of the wells)

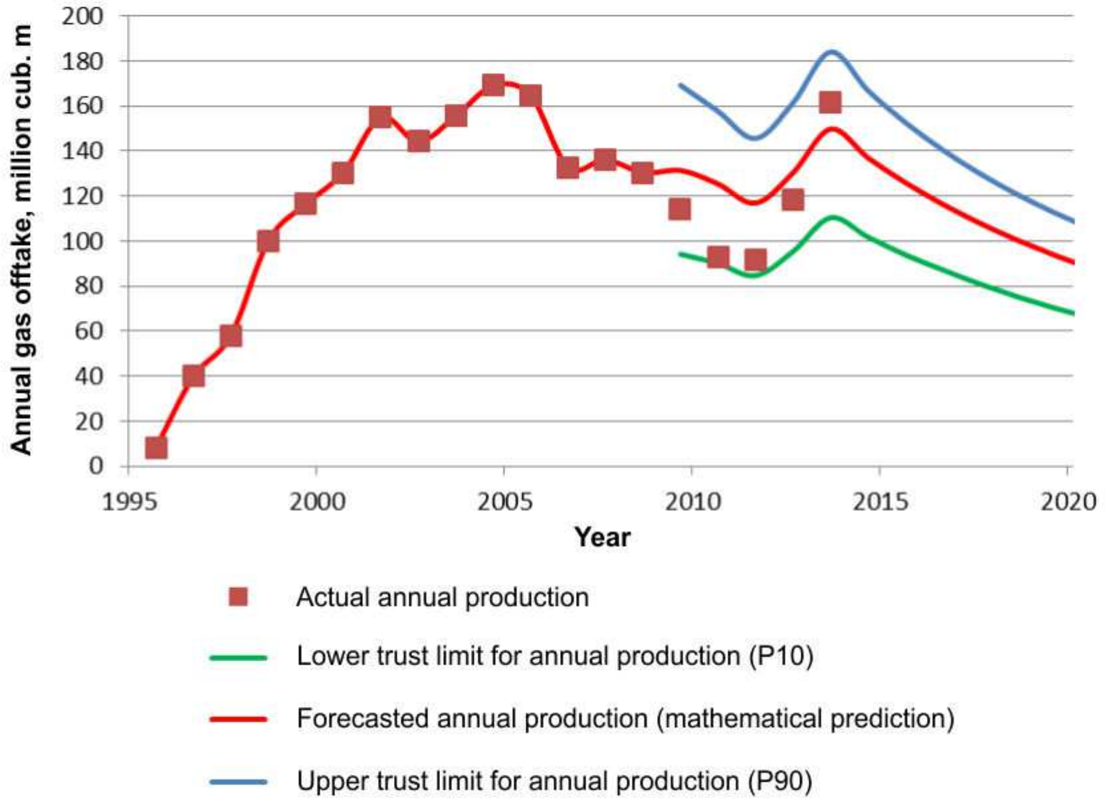

Figure 7 – Results of the annual selection forecast for the first development facility of the East-Poltava field

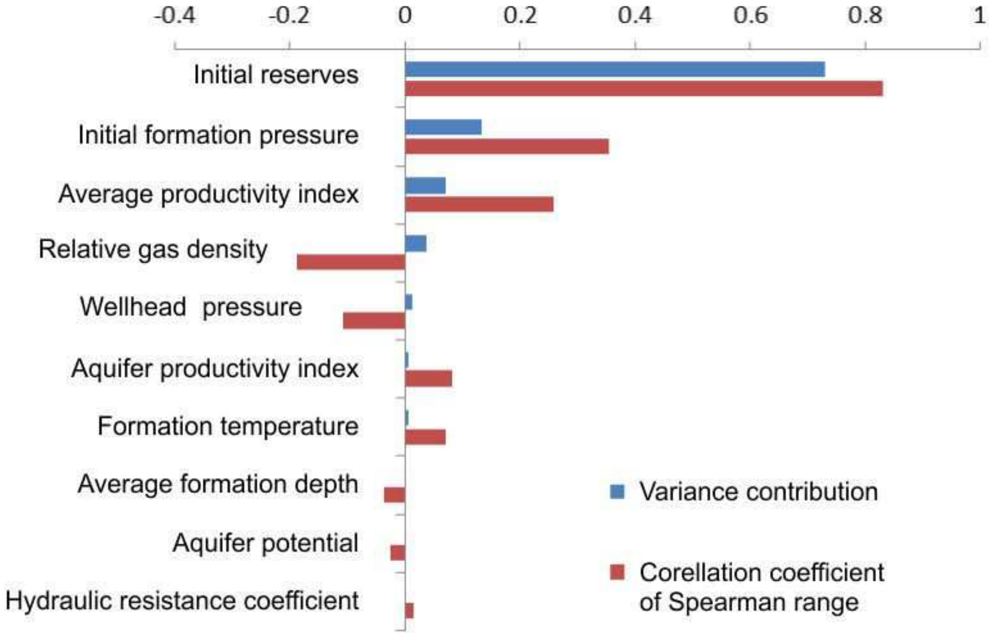

Figure 8 – Diagram of tornado risks for annual selection (2020) of the first development facility of the East Poltava field

of the forecast depends almost exclusively on the accuracy of the determination of gas reserves. The material balance algorithm allows us to clarify the gas reserves when adapting the model to the reservoir pressure measurements in the wells, avoiding the ambiguous procedure for determining the weighted average reservoir pressure.

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УДК 622.276

Ризики прогнозування видобутку газу з використанням рівнянь матеріального балансу

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Received: 30.06.2016 Accepted: 12.10.2016

Оцінено ризики прогнозування основних показників розробки газового родовища із використанням системи рівнянь матеріального балансу. За фактичними даними побудовано оцінки впливу складових рівнянь матеріального балансу, алгоритму загалом і точності вхідних даних на достовірність прогнозування відбору газу. Показано, що переважний внесок у варіацію прогнозних показників пов'язаний із точністю визначення початкових видобувних запасів.

Ключові слова: *алгоритм, газ, матеріальний баланс, поклад, прогнозування, ризики.*