On the Need to Solution Some Problems of the Development of Gas Fields on the Basis of the Evaluation of their Reserves by Different Methods

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Abstract: The results of numerical experiments on the calculation of gas reserves by volumetric, pressure drop and statistical methods of the North Guzar field presented. It is shown that by comparing the results of calculating the value of gas reserves by various methods, it is possible to assess the volume of drained reserves, the effectiveness of geological and technical measures and justify the expediency (if necessary) of refining their approved value.

Keywords: gas reserves, estimation method, volume, pressure, statistics, dependence, coefficient, correlation, development, discrepancy, measure, efficiency.

One of the priority areas of the oil and gas industry is the discovery of new fields and an increase in natural gas reserves. Currently, about 90% of hydrocarbon production and up to 70% of the annual increase in hydrocarbon reserves of the Republic of Uzbekistan is in the Bukhara-Khiva oil and gas-bearing region. In this region, the main volume of production and growth of gas reserves is associated with the Jurassic carbonate formation, which has been the main target of gas prospecting, exploration and development for more than 40 years [1].

Due to a high degree of study of the carbonate formation, the probability of discovery of large and medium hydrocarbon deposits is low. At the same time, the share of discovery of small deposits containing gas reserves from 1 to 10 million TTC is increasing. Examples are the gas and gas condensate fields of Tavakkal, Nishan, Devkhana, Ernazar, Chigil, Nazarkuduk, North Girsan, Talimarjan and others discovered in recent years. At these fields, there are certain difficulties in the question of reliable definition of gas reserves in connection with the limited fund of wells and large ranges of changes in calculation parameters.

The value of gas reserves is the basis for the adoption of predictive indicators of development and technologies for their extraction. The unreliability of this parameter, both in the direction of decrease and in the direction of its increase in the development process, leads to changes in previously adopted technological solutions, unjustified consumption of material and technical resources and financial costs, which reduces the efficiency of the operation of natural gas fields. Increasing the degree of reliability of gas reserves calculation allows making reasonable design decisions, which ultimately leads to an increase in the efficiency of its extraction, rational use of material and technical resources, and financial capabilities of the enterprise.

The application of methods for calculating gas reserves and their reliability depend on the stage of exploration of the field. At present, depending on the stage of exploration of the field, the volumetric method, the method of material balance (by pressure drop), statistical regularities, and geological and mathematical models are widely used to determine gas reserves.

The volumetric method for calculating gas reserves has found the widest application, because. This method is applicable at any stage of reservoir development and reservoir, energy manifestation modes.

The most common factors affecting the accuracy of gas reserves determination by volumetric method include in homogeneity of the reservoir in the section and area; anisotropy of formations. Presence of litho logical screens, position of gas-water or gas-oil contact in the presence of oil rim, configuration of gas-bearing area, effective gas saturation thickness, saturation of porous medium with gas, water, oil; mobility threshold of fluids, etc. [2].

The main disadvantage of the volumetric method is that not only filtration parameters are not taken into account when calculating gas reserves, but also low-porous and low-permeability interlayers are excluded from the calculation of reserves.

The accuracy of determining gas reserves by the material balance method depends on the reservoir regime. High accuracy of gas reserves determination by this method can be guaranteed if a deposit with a gas mode and homogeneous in terms of capacitance and filtration parameters is fully involved in development.

Statistical dependences - regularities of gas withdrawal changes during the period of declining production, established because of generalization of materials on the development of fields at the late stage of operation. The necessary condition for application of this method is absence of changes in the implemented development system during the considered period (covering the actual period of withdrawal changes and the extrapolation time). This method cannot take into account changes connected with DCS commissioning, watering rate of well production, fluctuations of technological mode of well operation on limitation or increase of flow rates of the latter, etc.

The emergence of methods of using geological and mathematical models caused by the inaccuracy of other methods that do not take into account the filtration properties of gas-bearing formations when calculating gas reserves.

The theoretical basis of this method of calculating gas reserves is the use of a system of unsteady multiphase three-dimensional filtration equations in a heterogeneous multilayer anisotropic porous medium of gas to describe the process of field development, condensate (in gas and oil fields), oil and water (bottom or contour) taking into account gravitational and capillary forces, change of fluid properties in porous medium from pressure, mutual solubility of fluids and other factors in massive and reservoir types [2, 3].

Difficulties in applying geological and mathematical models to calculate gas reserves are mainly due to the lack of providing the necessary information about the geological structure of the reservoir, heterogeneity of reservoirs, measurements of fluid properties during operation and other parameters, especially at the early stages of field development.

Let us consider the application of the results of gas reserves calculation by volume, pressure drop and statistical methods for solving development problems, by the example of the North Guzar field.

The North Guzar gas-condensate field discovered in 1991, with productive XV and XVa horizons associated with Upper Jurassic carbonate sediments. Dolomites and limestone represent XV and XVa horizons.

The North Guzar structure is a north-east-trending brachiate anticline, complicated by a tectonic disturbance that cuts the southeastern wing of the fold. Its isohypseal dimensions are 2,600 m to 6.4 x 1.7 km, and its height is 190-200 m. Horizons XV and XVa represent a single gas-bearing reservoir with a common gas-water contact.

Open porosity of dolomite horizons XV and XVa varies from 1.9 to 13.9%, permeability from 0.01 to $46.8 \cdot 10^{-3}$mkm^2. Open porosity of limestone of these horizons varies from 2.2 to 8.5% and permeability from 0.01 to $0.5 \cdot 10^{-3}$mkm^2. Limestone and dolomites of XV and XVa horizons characterized as fracture-pore type reservoirs.

Average reservoir pressure values are as follows: in the upper part of the reservoir - 32.38 MPa, in the middle part - 32.9 MPa, at the GVK mark - 33.04 MPa. Abnormality coefficients of reservoir pressure vary from 1.075 and 1.078 in the lower part of XVa horizon to 1.113 and 1.103 in the upper part of XV horizon.

The average value of reservoir temperature in the gas reservoir of XV horizon is +111.9 ^{0}C, in the middle of XVa horizon +112.6 ^{0}C. The average value of the geothermal gradient is 2.23 ^{0}C/100 m, and the geothermal stage is 46.19 m/^{0}C.

The North Guzar field put into development in 2007. Growing hydrocarbon production in 2007-2009 caused by outstripping drilling of wells. Maximum production of gas and condensate reached in 2009 in the amounts of 88,225 and 163,887 TOF.

The sharp decline in production since 2010 was due to increased water cut of well production, which resulted in the deterioration of filtration-volume properties of the well bottom whole zone. The production of the operating well stock and a decrease in reservoir pressure from the initial 31.7 to 17.0 MPa.

As of 01.01.2015, 13 wells were drilled at the field, 7 of which are active (№№ 1, 5, 9, 10, 11, 12, 13), 1 well is waiting for cattle, 1 well (№ 6) is in the control stock and 4 wells (№№ 2, 3, 4, 7) are liquidated.

The following technological indicators characterize the development of the North Guzar field:

- accumulated gas production of 3,426,904 TFT (ton of standard fuel) or 32.37% of its approved reserves;
- Condensate condensate of 556084 TFT (ton of standard fuel) or 22.89% of its geological reserves was extracted from the subsurface;
- current reservoir pressure of 17 MPa, decreased by 53.6% compared to its initial 31.7 MPa.

Gas reserves calculated by the volumetric method according to the formula[2]:

$$Q_g = S \cdot h \cdot K_p \cdot K_g \cdot (P_{pl} \cdot \alpha_{pl} - P_0 \cdot \alpha_0) \cdot f \cdot \eta, \quad (1)$$

S –Gas-bearing area, thousand $м^2$;

h – effectivegas – saturatedthickness, м;

K_p –porosity coefficient;

K_g –gas saturation coefficient;

P_{pl}, P_0 – initial and final reservoir pressure ($P_0 = 1$);

α_{pl}, α_0 –corrections for deviation of real gases from Boyle-Mariotte law (α_0=1);

f −temperature correction;

η −conversion factor for dry gas.

We will take the estimated parameters and gas reserves in accordance with the report on the operational calculation of the reserves of the North Guzar gas condensate field in the amount of 9,618 thousand tons of oil equivalent, approved by the CDC NHC "Uzbekneftegaz" [4].

According to the pressure drop method based on constructing the relationship between the cumulative gas production and the reduced reservoir pressure (defined as the ratio of reservoir pressure and gas compressibility factor), the value of gas reserves (P) was obtained equal to 6929.6 thousand TFT (ton of standard fuel), which is 67.33% of reserves calculated by the volumetric method (V).

In practice, there can be three cases of the ratio of gas reserves calculated by volume and by the pressure drop method: V> P; V≈ P and V< P. The first case, in which V> P, is usually explained by incomplete drainage coverage of the gas-saturated volume of the reservoir and is often the basis for compacting the density of the well pattern to increase the degree of gas recovery. The second case, when V≈P, indicates the almost complete drainage coverage of the entire gas-saturated volume of the reservoir and the possibility of achieving the design value of gas recovery. In the third case, when V<P, there is a need to clarify gas reserves. To clarify gas reserves and their causes, it is advisable to use geological and mathematical models.

To increase the reliability of the reasons for the deviation of gas reserves calculated by the volumetric and pressure drop method, in our opinion, it is advisable to consider an additional criterion. Which is the ratio of the current and initial reservoir pressures P¯ (P¯=P_(pl.t)⁄P_(pl.n) , where P_(pl.p) is the initial reservoir pressure, P_(pl.t) is the current reservoir pressure) and the ratio of cumulative gas production and its approved initial reserves Q¯(Q¯=∑▒Q_g⁄Q_nz , where ∑▒Q_g - cumulative gas production, Q_nz - initial gas reserves).

- When comparing the values of P¯and Q¯, there can also be three cases:
- at P¯>Q¯the conclusion is confirmed by the incomplete drainage coverage of the gas-saturated volume of the deposit and the need to reassess the gas reserves, because its value may be less than the approved one;
- at P¯≈Q¯the conclusion about the complete coverage of the gas -saturated volume of the deposit by drainage and confirmation of the value of the approved reserves is confirmed;
- at P¯<Q¯, the conclusion about the need to recalculate gas reserves is confirmed, since its value may be greater than the approved one.

Calculation of gas reserves of this field by a statistical method carried out according to various models. Numerical experiments have shown that the highest correlation coefficients achieved for four of them.

The calculations of the dependence of the logarithm of the cumulative gas production (lg Q_g) on the development period (t) show that this dependence is quite well (with a correlation coefficient r = 0.9475) described by a mathematical model of the form (Fig. 1):

$$(lg\Sigma Q_g) = -0{,}0420 \cdot t^2 + 0{,}5218 \cdot t + 2{,}6361. \qquad (2)$$

A similar formula, but with a higher correlation coefficient equal to 0.9714, describes the dependence of annual gas production on its cumulative production (Qg) (Fig. 1)

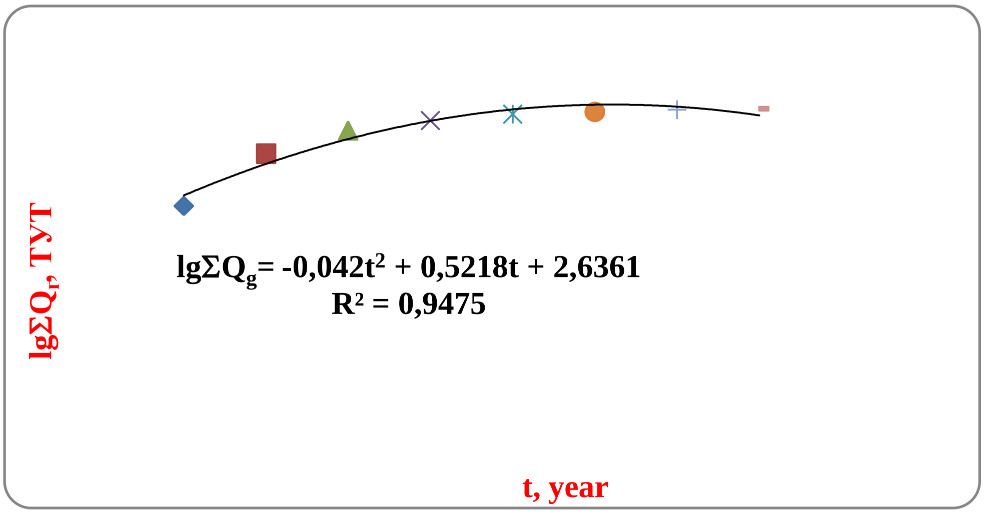

Fig. 1. Dependence of the logarithm of accumulated gas production on the development time

$$Q_g = -0{,}2841 \cdot \Sigma Q_g^2 + 0{,}9699 \cdot \Sigma Q_g + 0{,}0629. \quad (3)$$

The dependence of the logarithm of annual gas production on the development period described (with a correlation coefficient of 0.9292) (Fig. 2).

$$lgQg_g = -0{,}0540 \cdot t^2 + 0{,}3838 \cdot t + 2{,}8891. \quad (4)$$

The model proposed by A.V. Kopytov, in the form of the dependence of the product of cumulative gas production and development time on the development time, distinguished by the highest correlation coefficient from all the considered statistical approaches. This relationship well described by a linear relationship with a correlation coefficient of 0.9949 (Fig. 3.4).

$$Q_g \cdot t = 4{,}0449t - 5{,}0411. \quad (5)$$

For all these options, a forecast of cumulative gas production for a 10-year period of field development made, shown in Table. 1. It can be seen from it that the obtainedvalues of cumulative gas production from 3450.9 to 3654.1 thousand TFT (ton of standard fuel) are very close, i.e. the discrepancy is only 5.56%.

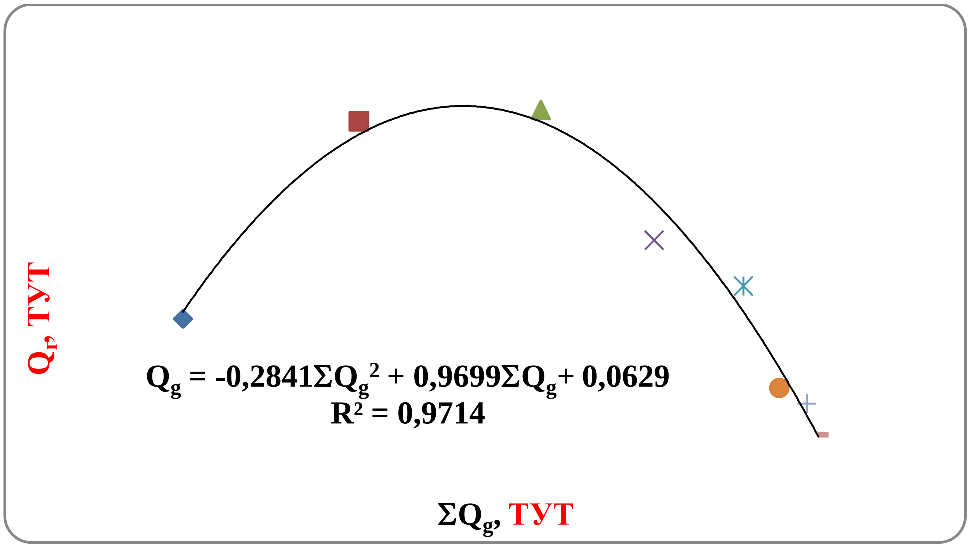

Fig. 2. Dependence of annual gas production on accumulated gas production

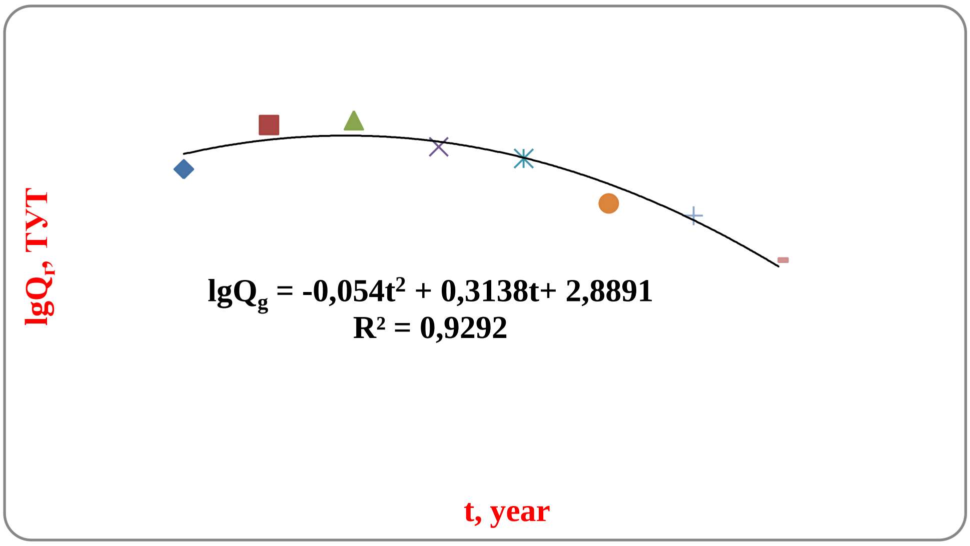

Fig. 3. Dependence of the logarithm of annual gas extraction on the development time

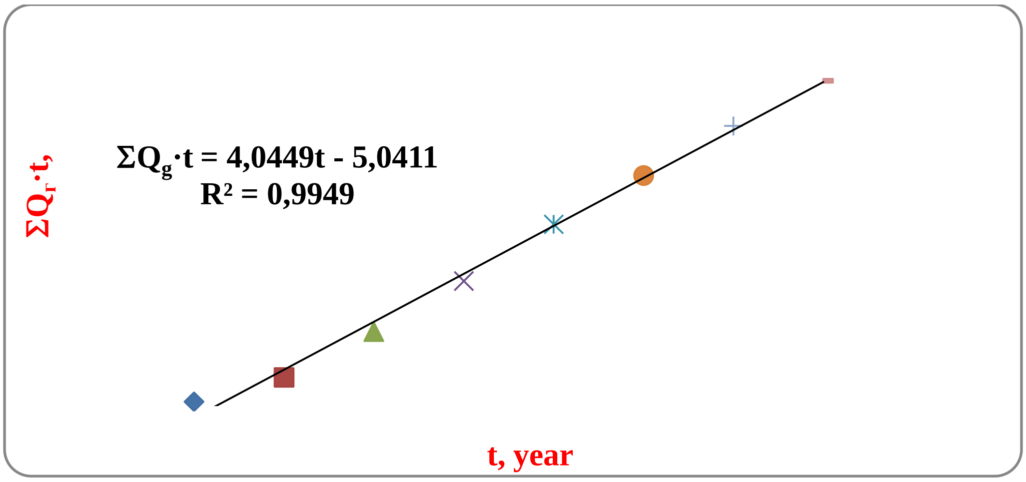

Fig. 4. Dependence of the product of accumulated gas production and development time on development time

Table 1. Forecast of cumulative gas production at the North Guzar field using statistical models

№№	Static model	Correlation coefficient	Accumulated gas production for the development period, thousand TFT (ton of standard fuel)
1	$lg\Sigma Q_г = -0{,}042 \cdot t^2 + 0{,}5218 \cdot t + 2{,}6361$	0,9475	3654,1
2	$Q_г = -0{,}2841 \cdot \Sigma Q_г^2 + 0{,}9699 \cdot \Sigma Q + 0{,}0629$	0,9714	3450,0
3	$lgQ_г, = -0{,}054 \cdot t^2 + 0{,}3138 \cdot t + 2{,}8891$	0,9292	3492,3
4	$\Sigma Q_г \cdot t = 4{,}0449 \cdot t - 5{,}0411$	0,9949	3640,1

At the same time, the average value of cumulative gas production is less than its value calculated by the volumetric method by 6,732.65 thousand TFT (ton of standard fuel), i.e. is 34.58% of its value. The main reason for such a large discrepancy in the value of gas reserves for these two methods is that 6 statistical models do not take into account possible changes in the implemented development system, in particular, the commissioning of BCS, changes in the technological mode of well operation, drilling of new gas producing wells, etc. In the cases described, statistical models can be used to evaluate the effectiveness of changes carried out at the site in the implemented development system and geological and technical measures.

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