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The calculation algorithm of the operating mode of production well for concentric lift columns in conditions of the accumulation of liquid at the bottom

The article proposes a solution to the problem of operating wells at the bottom of which fluid accumulates during the production of reservoir products (using the example of producing wells of the Cenomanian deposit of the Urengoy oil and gas condensate field of Gazprom Dobycha Urengoy LLC, Russia). It is shown that traditionally this field problem is solved by carrying out underground repairs, which creates the risk of the wells not being brought back to the initial parameters, primarily in terms of flow rate. It was also noted that it becomes impossible to operate the wells of the Cenomanian deposit in the conditions of the collapse of the bottom-hole zone of the reservoir with the periodic shutdown of the gas flow from the annulus. The solution to this type of complication in the wells of the Cenomanian deposit of the Urengoy oil and gas condensate field is to transfer the wells to operation using concentric lift columns. This relatively new innovative technology allows for the removal of liquid from the bottom together with gas, thereby avoiding closing the well and its subsequent repair, as well as possible stimulating treatments to restore the necessary flow. The conditions of the transition to the operation of wells in concentric lift columns with the aim of removal of the liquid phase by the gas stream are considered. The methodology for calculating the operating mode of the well of the Urengoyskoye field using concentric lift columns is considered with the aim of ensuring the removal of liquid from the bottom using the software package. It is shown that by calculating the dependencies and the software package, it is possible to determine the critical and recommended flow rate (with a margin of 10-20%) for the well to work without complications in the conditions of sand development and accumulation of liquid at the bottom.

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1. Introduction

As known, at the final stage of the development of gas and oil and gas condensate fields, a number of complications may arise that worsen operating conditions and reduce their production capabilities. One of these types of complications may be the process of accumulation of liquid at the bottom and in the wellbore that cannot be carried to the surface due to insufficient upstream gas flow rates (Yushin, 2019).

Currently, the Urengoy oil and gas condensate field (UOGCF), located in the Yamal-Nenets Autonomous Okrug of Russia, the number of gas wells of the Cenomanian reservoir, working with the accumulation of liquid in the bottom, is 37% of the total operating fund.

It is worth noting that, traditionally, the accumulation of liquid at the bottom of the wells is eliminated by underground repairs, and, consequently, the well is shut off, which entails such a commercial problem as returning to the previous operating mode while maintaining the rate of formation in production rate. However, this is not always possible to achieve, which allows us to judge the effectiveness of the well repair work performed.

The fields of the Nadym-Pur-Taz region are characterized as one of the most complicated in the Russian territory by the accumulation of liquid on the face, which reduces production indicators.

1.1 Geological and technological measures for the wells stable operation

The following geological and technological measures are used at gas fields in Russia and abroad to maintain the stable operation of wells in which fluid accumulates in the trunk:

- Technological flushing of wells is carried out through a flare line for periodic removal of accumulated water;
- Use liquid and solid foaming surfactants, periodically delivering them to the bottom of the wells;

- Carry out the replacement of pipes of the lift columns to pipes of smaller diameter to increase the gas flow rate.

In recent years, other technologies that are used in world practice to increase the efficiency of operation of waterlogged wells are actively tested in Russia: injection of additional gas into the annulus (gas lift), plunger lift, etc.

Technological purges are the most widely used to remove fluid from the wells of Cenomanian deposits, accompanied by large losses of gas into the atmosphere. At the same time, depressions during blowdowns increase significantly and often lead to the destruction of the bottom-hole zone, sand removal, and abrasive wear of the equipment.

Foaming surfactants can significantly reduce gas losses due to technological purging of wells, and in some situations, eliminate them completely. However, technological purges with or without foaming surfactants do not completely remove water from the well.

1.2. Effect of the pipes replacement

The increase in gas velocity in the wells of the Cenomanian deposits by replacing the pipes of the lift column with pipes of a smaller diameter is carried out to create conditions for the removal of water from the lift columns. After replacing the pipes, the wells operate in a stable mode, the fluid in the tubing does not accumulate, but within 8-15 months after the replacement of the pipes of the elevator string, the conditions for water removal will again worsen to the original conditions. Replacing the tubing is accompanied by a decrease in the working flow rate of wells by 20-50%.

With a steady decrease in the flow rate below the critical value at which the fluid cannot be removed from the well, which leads to its self-squeezing, as well as in those wells of the Gazprom fields where sand development is active, the mine workings are being reconstructed and put into operation according to internal developed regulations on concentric lift columns (CLC). In addition, the use of CLC technology allows you to abandon the technological purging of wells into the atmosphere.

It is worth noting that since 2000, the technology of operating wells in concentric lift columns began to be used in the wells of fields in the USA and Canada, but the operation of the wells of the Cenomanian deposits is complicated due to the destruction of the bottom-hole zone of the reservoir, sand removal from the wells and as a result of equipment abrasion. Given the increased sand development, a scenario with the periodic shutdown of the gas flow from the annular casing space is impossible, therefore, for a number of foreign fields with similar characteristics, the methodology under consideration is relevant. Various problems of the movement of gas-liquid flows in the well were considered in foreign publications (Garrouch et al., 2019; Yasin et al., 2014; Lea and Nickens, 2004; Limpasurat et al., 2015; Agrawal and Sharma, 2013; Luo et al., 2014; Riza, 2013; Waltrich et al..., 2013; Yuan et al., 2013; Alamu, 2012) by well-known scientists.

At the same time, for flooded wells of Cenomanian deposits, during the final development stage, the most promising optimization scenario is the exploitation of CLC wells with automatic maintenance in the central elevator string (CES) of gas production exceeding by 10÷20% the minimum value required to remove fluid by CES.

1.3 The aim of the research

Thus, the aim of this work is to consider the conditions for the application of advanced technology for producing wells using concentric lift columns with an accumulation of liquid at the bottom, as well as a calculation algorithm for calculating the critical and recommended flow rates for good operation without complications.

2. Materials and methods

The ÑLÑ well operation technology using a two-row elevator or a two-channel scheme is a process used to operate gas and gas condensate wells, in which the gas from the reservoir is divided into two streams at the bottom. Gas flows rise through the channels formed by two pipe columns: the CES and the main lift one (MLC), concentrically placed one in the other and communicating at the bottom with each other. MLC is composed of tubing or boring casing of various sizes, while the CES is an elevator of a smaller diameter, concentrically located in the MLC. After the gas rises to the wellhead, gas flows are connected and enter the gas collector.

The methodology of the work includes the sequential implementation of such stages as the choice of the design of a concentric column under a number of key conditions, the presence of complications in the production of gas or gas condensate in the candidate well, and the calculation of the main parameters (critical and recommended flow rates) in the software package (Yungmeyster and Isaev, 2017; Yungmeyster et al., 2018; Dzhevaga and Lobacheva, 2019).

To test the CLC technology in the wells of the Cenomanian deposit of the UOGCF, the column design was chosen. In order to minimize the likelihood of complications during the launching of the reinforced polymer pipe, a sample of wells with large-diameter tubing was selected at Gazprom Dobycha Urengoy LLC for field tests. For lifting to the surface of the gas, the wells are equipped with tubing lift columns made up of flexible load-carrying polymer pipes with nominal outer diameter from 73 to 168 mm.

Further, the following conditions were required:

- Lack of plans for major repairs in the near future;
- The presence of condensation or condensation and man-made water;
- The well is equipped with a control system and telemetry of wellhead parameters;
- The operation of the well is complicated by stops with

flushing to the torch at least once every 10-15 days;

- The estimated velocity of the gas-liquid flow at the tubing shoe is not more than 4 m/s.

3. Results

3.1 Scheme of gas wells opening and their operating parameters

The above factors, taking into account the insignificant distance from the field, can be met by well No.514 as an object for field testing. In the production fund of the fifth gas field, the well has been located and is part of unit No.51 since 1981.

Fig.1 shows a scheme for opening this lease with four gas wells, and the operating parameters are given in Table 1.

According to geological and field data in all wells of the cluster No.51, with the exception of well No.511, in the period 2008-2012, well overhaul (WO) work was completed, accompanied by well closing. In well No.514 in 2010, work was carried out to intensify the influx using hydrochloric acid.

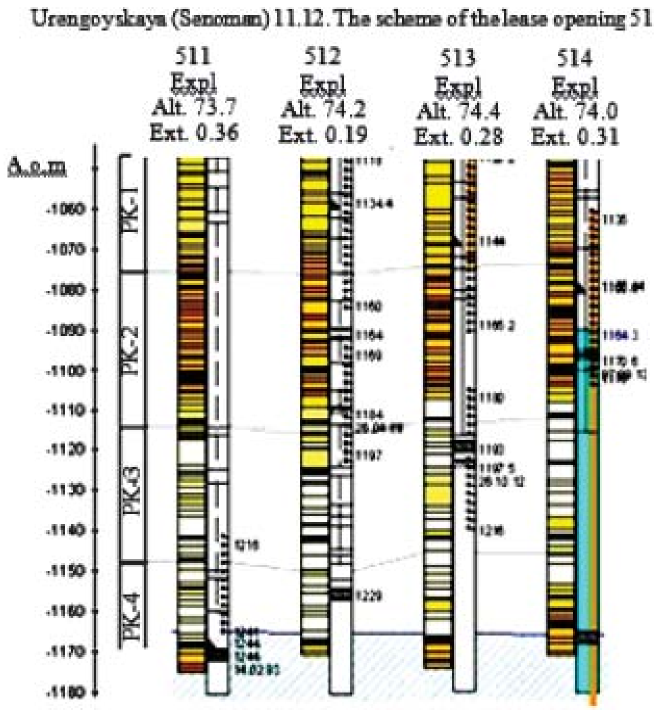

Fig.1 The scheme of opening the lease number 51 UKPG-5

3.2 Liquid state in the well

These works led to an increase in water mineralization to 49.5 g/dm^3 due to the presence of anthropogenic liquid in it, as evidenced by the high content of chlorides and calcium in the liquid sample (Table 2). In 2012, washing of the sand plug was carried out (Dzhevaga and Lobacheva, 2019).

According to field geophysical research, well No.514 is filled with process fluid to a depth of 1169.0 m. As of July 1, 2013, the gas-water contact (GWC) along bush No.51 is located at a depth of 1236 m (Table 3). The distance from the lower perforation holes of well No.514 to the surface of the

Table 2: The composition of the water coming from well No.514 UKPG-5 before the introduction of innovative equipment and technologies

	The name of indicators	Value
1	Date	10.10.2013
2	Density at 20°C, g/sm^3	1.036
3	PH value	4.17
4	Chloride ion, mg/dm^3	31517.00
5	Total hardness, mEq/dm^3	645.00
6	Bicarbonate ion, mg/dm^3	not identified
7	Calcium, mg/dm^3	10922.00
8	Magnesium, mg/dm^3	1216.00
9	The sum of potassium and sodium ions, mg/dm^3	5851.20
10	Total mineralization, mg/dm^3	49505.85
11	Reduced mineralization, mg/dm^3	-
12	Methanol content, % wt.	-

Table 3: Design of the well No.514 of the cenomanian deposit UOGCF

Parameter	Value
Direction	426 mm × 145 m
Conductor	324 mm × 574 m
Production tower	219.1 mm × 1251m
HKT	168.3 mm × 1155.1 m
Packer	Extracted
Perforation range	1135÷1178 m
Current bottom hole	1170.6 m
Plug back total depth	1241 m
Current GWS according to GIS	1239 m

Table 1: Operation parameters and geological and field data of wells of lease No. 51 of UKPG-5

No. of well	Monthly maintenance report data			Geological and production data	
	p_y, MPa	t_y, °C	q_{cp}., thousand m^3/day	M_{total}, g/dm^3, recovery date	WO date
511	14.5	12.7	214	0.1410.10.2013	–
512	14.1	4	60	0.1711.10.2013	06.2008 – tubing audit
513	14.1	7.6	79	0.1329.11.2013	05.2008 – tubing audit
514	14.1	3	75	49.510.10.2013	07.2010 – WO to intensify the influx 09.2012 – sand plug flushing

GWC is 63 m. 168 mm lift column was lowered into well No.514, cased with a production string with a diameter of 219 mm and a length of 1251 m. The shoe of this column is located at a depth of 1155 m. The packer was removed from the well. During the operation, the reservoir pressure decreased from 1.1 MPa to 1.75 MPa. The bottom hole temperature in the wells of bush No. 51 is 27°C.

In November 2013, a previously periodically idle gas production well No.514 of well 51 of UKPG-5 lease was equipped with a CLC and a tele-mechanics complex for gas well clusters. On December 16, 2013, well No.514 was put into operation and is currently being stably operated at UKPG-5. For all the time, there was not a single case of good shutdown due to the accumulation of liquid at the bottom and a decrease in gas production. Water removal takes place automatically through the central elevator column under the control of a technological complex for monitoring and controlling gas well operation modes. For the first time, the Russian steel-polymer reinforced pipe TG19/73-10/10-75 was used as the CES.

3.3 Pressure and Temperature Parameters at the Head of the Well

The state and operating parameters at the wellhead are displayed in real-time on the automated workplace CGTP and in the dispatch management information system of the LLC Gazprom Dobycha Urengoy. The effectiveness of such control is illustrated in Fig.2.

As can be seen from the diagram, in separate periods of time, due to pressure fluctuations in the gas gathering line header, the wellhead working pressure increased to 1.65 MPa. The consequence of this was a decrease in the speed of the gas-liquid mixture, gas production rate decreased, water accumulated at the bottom, and there were spontaneous shutdowns of the well. To resume work, purging the well was carried out on a flare, as evidenced by a decrease in pressure to 0.7 MPa about 1-2 times a week. The information presented characterizes well No.514 as a typical representative of the gas production well stock of the Cenomanian deposits of the Urengoy field. Based on the foregoing, well No.514 was selected as the primary candidate for field testing of new equipment and technology for reconstruction and operation of the CLC.

3.4 Criteria of the Well Fluid Level

The criterion for the selection of waterlogged gas wells for commissioning using CLC technology is the presence of signs of fluid accumulation at the bottom and in the elevator string. Possible signs of a dynamic fluid level in the well should be considered:

- The presence of pressure surges recorded by the wellhead telemetry monitoring system;

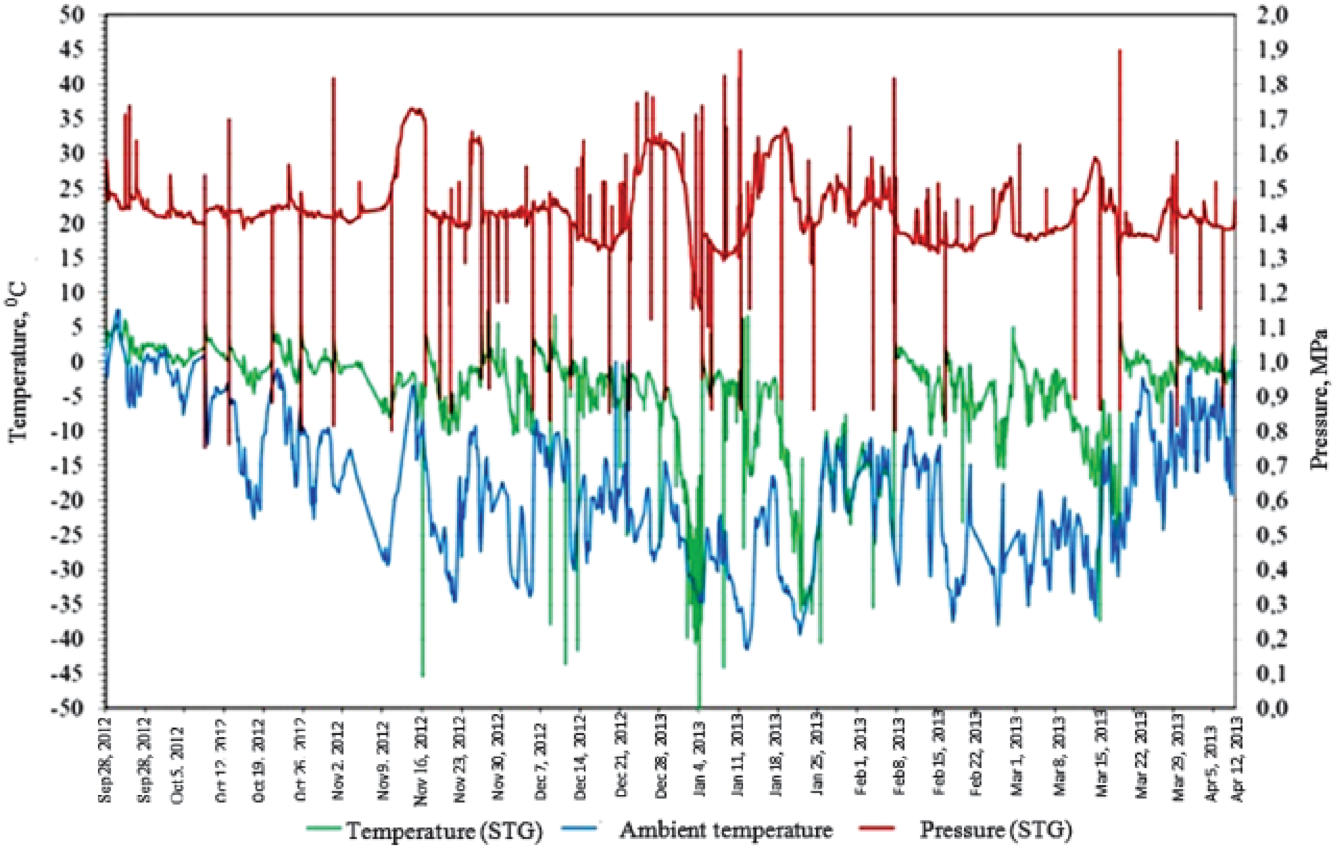

Fig.2 Change in pressure and temperature at the head of the well No. 514 UKPG-5

- Uneven production and an increase in the rate of decline in production;
- Pressure drop in the tubing (LC) with increasing pressure in the annulus;
- A sharp change in the pressure gradient along the wellbore; rise in the level of carbonated liquid in the well.

Candidate wells for liquid removal using the technology of exploitation of water-logged gas wells on the CLC are wells with a gas flow rate insufficient for continuous fluid removal. To assess the flow rate of gas, insufficient for the continuous flow of fluid, calculate the minimum flow rate of gas, below which the accumulation of the liquid phase at the bottom of the well occurs.

3.5 Gas flow rate study

Minimum gas flow rate Q_{min}, thousand m^3/day, is calculated by the formula:

$$Q_{min} = 86.4 \cdot V_{min} \cdot \frac{\pi \cdot d^2}{4} \cdot \frac{P}{P_0} \cdot \frac{T_0}{Z \cdot T} \quad \text{... (1)}$$

where V_{min} is the minimum gas velocity necessary for the removal of fluid, m/s, is determined by the formula:

$$V_{min} = 3.3 \cdot \left(\frac{g \cdot \sigma \cdot \rho_1^2 \cdot sin(\alpha)}{\rho_2^2 \cdot (\rho_1 - \rho_2)}\right)^{0.25} \quad \text{... (2)}$$

where d is the inner diameter of the LC, m; P is bottom hole pressure, MPa; P_0 is pressure under standard conditions, MPa; T_0 is the temperature under standard conditions, K; Z is the coefficient of super-compressibility of gas at the bottom; T is the bottomhole temperature, K; g is the acceleration of gravity, m/s^2; σ is the coefficient of surface tension of the liquid, N/m; ρ_1 is the fluid density, kg/m^3; α is the angle of inclination of the LC to the horizon, deg; ρ_2 gas density at the bottom, kg/m^3.

If the actual gas production rate is less than the calculated value of the minimum gas production rate multiplied by a coefficient of 1.05–1.10 with the maximum allowable depression per formation, then such a well is a candidate for using CLC to remove fluid from the bottom.

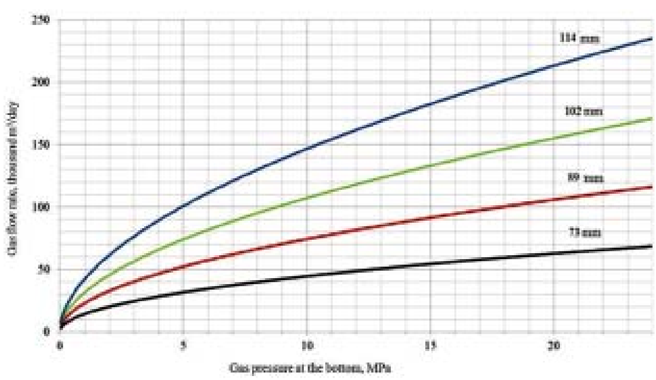

Fig.3 The average daily gas production rate, at the reduction of which it is advisable to use the technology (for various D_{head} of the main lift column D_{mlc})

CLC technology is used with a steady decrease in flow rate below a critical value at which the fluid is not removed from the well, which leads to self-squeezing, or when fluid accumulates in the well that cannot be carried out under the existing regime (Fig.3). The technology is used both independently and in conjunction with other technologies for the operation of self-filling wells.

The area of independent application of well operation technology for CLC is determined by the boundary condition. For the selected D_{CES} (the inner diameter of the pipes of the central lift column), with a closed casing-tubing annulus (CTA) in the working range of possible pressure fluctuations in the gas collection manifold, the gas production rate on the CES must exceed the minimum flow rate at which the liquid is removed, 1.1–1.2 times (Fig.4). If the indicated parameters do not provide fluid removal through the central column, then the CLC well operation technology is used in conjunction with other water-logged gas well operation technologies.

If the gas production rate for the CLK is lower than critical values and the well is unstable due to the accumulation of liquid at the bottom, it is recommended to use a surfactant (in accordance with the technological regulations for the use of surfactants).

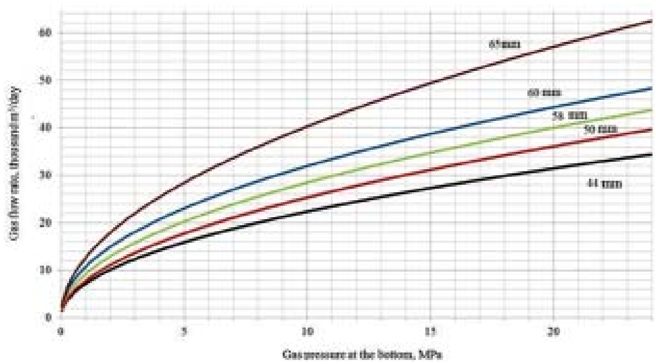

Fig.4 The minimum gas flow rate in a closed inter-ring space, at which the application of technology is acceptable (for various diameters of the central elevator column)

3.6 Algorithm for calculating the operating modes of wells equipped with a concentric lift column

CLC technology can be used in sand producing wells. In such wells, it is recommended to carry out work on fastening the bottomhole formation zone (BHFZ) during the workover associated with good reconstruction. Depression on the formation should not exceed the maximum value determined by the results of hydrodynamic studies (HDS) after reconstruction. The following is an algorithm for calculating the operating modes of wells equipped with a concentric lift column.

1. Basic input data for calculation:

a. absolute pressure in the reservoir P_{res}, MPa;

b. absolute pressure in the gas manifold P_{man}, MPa;

c. filtration coefficients of gas inflow to well bottom formula a and b;

d. CES length L_{CES}, m;

e. the inner diameter of CES pipes D_{inn}, mm;

f. the inner diameter of the pipes of the external elevator column D_{ext}, mm;

g. relative density of gas $\bar{\rho}$, kg/m^3;

h. gas temperature: in the reservoir is T_{res}, K; at the wellhead T_{head}, K;

i. geological and technical maximum flow rate Q_{max}, thousand m^3/day.

2. Additional data for calculation and decision making during good operation using a double-row concentric elevator

- current flow rate Q, thousand m^3/day;
- absolute wellhead pressure P_{end}, MPa;
- absolute pressure in the annular casing channel at the wellhead P_{an}, MPa;
- actual or calculated fluid flow rate Q_{fl}, m^3/day;
- fluid density ρ_{fl}, kg/m^3;
- fluid composition: condensate; condensation water; formation water;
- actual coefficient of resistance λ_{act} and annulus casing channel λ_{an};
- rate of change in reservoir pressure, MPa;
- manifold pressure change rate, MPa;
- ranges of pressure changes in the collection manifold depending on the actual gas consumption during the day, during the week, during the month, during the quarter.

3. Calculation of well flow rate during operation only for the central elevator string

If the well operates with a flow rate equal to or greater than the base one and formation water is supplied in a small amount, then the flow rate of the well is calculated by the formula (5), sequentially setting the numerical values of the pressure at the wellhead. The pressure change step is set based on specific conditions.

4. Calculation of the flow rate of the well during operation at the same time on the CES and annulus casing channel:

- determine the effective diameter by the formula (3);
- determine the flow rate of the well by the formula (1), replacing in the coefficient of resistance of the wellbore D by D_{ef}, calculated by the formula (8).
- determine the required value of the basic flow rate according to the CLK according to the formula (6), while the value of the reduced Froude parameter, which ensures the minimum pressure loss or flow rate required for continuous liquid removal, is determined experimentally depending on the diameter and quality of the pipes, the presence, and properties of the liquid (formation water or condensation, condensate, mixtures thereof). For approximate calculations, you can use the value of the Froude parameter equal to 500;
- calculate the gas flow rate on the annular casing channel according to the formula (4);
- a joint solution to the approximation method of equations (4)–(12) determine the dependence $Q = f(P)$.

When $P_{an} > P_{end}$ continues calculation at the next value P_{end}.

When $P_{an} < P_{end}$, the production rate on the CLK will be more than the set, the well leaves the control mode. In this case, the flow rate along the annular casing channel is limited to the maximum, and then the dependence $P=f(Q)$ is continued to be calculated.

Bottom hole pressure P_{bot}, MPa, calculated by the formula:

$$P_{bot} = P_{an} \quad \text{... (3)}$$

where P_{bot} is absolute gas pressure at the wellhead in the CTA when the gas moves only along the CLC (or gas pressure at the wellhead in the annulus when working on the CLC and CTA at the same time), MPa; S is a dimensionless indicator calculated by the formula:

$$S = \frac{0.03415 \cdot \bar{\rho} \cdot L_{ft}}{2 \cdot T_{av}} \quad \text{... (4)}$$

where $\bar{\rho}$ is relative gas density; L_{ft} is CES length, m; T_{av} is the average coefficient of gas compressibility corresponding to the value P_{av}, MPa, calculated by the formula:

$$P_{av} = \frac{2}{3} \cdot \left(P_{bot} + \frac{P_{end}^2}{P_{bot} + P_{end}}\right) \quad \text{... (5)}$$

where P_{end} is absolute pressure on the endplate, MPa; T_{av} is the average absolute temperature of the gas in the wellbore when the gas moves from the bottom to the mouth, K, calculated by the formula:

$$T_{av} = \frac{T_{end} + T_{bot}}{2} \quad \text{... (6)}$$

where T_{end}, T_{bot} is the temperature at the mouth and at the bottom, respectively, K.

5. Bottomhole pressure P_{bot}, MPa, when the gas moves along the CES at a flow rate greater than the base, calculated by the formula:

$$P_{bot} = \sqrt{P_{end}^2 \cdot e^{2 \cdot s} + \xi \cdot Q_{ft}^2} \quad \text{... (7)}$$

where Q_{ft} is an actual good production, thousand m^3/day; P_{end} is the absolute pressure at the wellhead, MPa; ξ is wellbore drag coefficient calculated by the formula:

$$\xi = 1.377 \cdot \lambda \cdot \frac{Z_{av}^2}{d_{in}^2} \cdot (e^{2 \cdot S} - 1) \quad \text{... (8)}$$

where λ is a coefficient of hydraulic resistance of the wellbore.

The average gas super-compressibility coefficient Z_{av} considered an iteration method using an approximating polynomial.

$$P_{av} = \frac{2}{3} \cdot \left(P_1 + \frac{P_{2k}^2}{P_1 + P_{2k}}\right) Z_{av} = z(\bar{p} \cdot \bar{T}) \quad ... (9)$$

where P_{av} is average absolute pressure, MPa; P_1 is the pressure at the inlet of the element (wellbore, flowline, etc.), MPa; P_2 is the pressure at the outlet of the element, MPa; k is an index related to i that is iteration.

$$\bar{p} = \frac{p_{av}}{p_{cr}} \bar{T} = \frac{T_{av}}{T_{cr}} \quad ... (10)$$

where P_{cr} and T_{cr} are critical pressure and temperature, MPa and K.

6. When gas moves along the annular casing channel, corrections are introduced to formulas (4) and (5) to calculate the bottom hole pressure from the pressure in the annular casing channel at the wellhead or the drag coefficient of the annular casing channel.

Instead of D_{in} effective diameter is introduced D_{ef}, mm, for the annular casing channel, which is calculated by the formula:

$$D_{ef} = \sqrt{D_{pr}^2 - d_{in}^2} \quad ... (11)$$

where D_{pr} is the inner diameter of the pipes of the external elevator (or production) column, mm.

Gas flow rate Q, thousand m^3/day, on the annular channel is calculated by the formula:

$$Qet = Q_{well} - Q_b \quad ... (12)$$

Instead of pressure on the head P_{head}, MPa, enter the pressure in the annular casing channel P_{an}.

7. Well production Q_{well}, thousand m^3/day, after removing the liquid from the CES is calculated by the formula:

$$Q_{well} = \frac{\sqrt{\left[P_{rest}^2 - P_{end}^2 \cdot e^{2 \cdot s}\right] \cdot \left[b + \xi \cdot z_{av}^2 \cdot (e^{2 \cdot s} - 1)\right] \cdot 4 + a^2} - a}{2 \cdot \left[b + \xi \cdot z_{av}^2 \cdot (e^{2 \cdot s} - 1)\right]} \quad ...(13)$$

8. The dependence of pressure loss during the movement of a gas-liquid mixture in a vertical pipe on the complex parameter Fr is calculated by the formula:*

$$Fr^* = 217 \cdot 10^{-6} \cdot \frac{\bar{\rho}_g}{\bar{\rho}_l} \cdot \frac{P_0}{g \cdot T_{cr}} \cdot B^2 \cdot Q^2 \cdot d^{-5} \quad ... (14)$$

where Q is the gas flow rate, thousand m^3/day; B is a complex coefficient calculated by the formula:

$$B = \sqrt{\frac{z \cdot T}{P}} \quad ... (15)$$

$\bar{\rho}_g$, $\bar{\rho}_l$ are relative densities of gas and liquid; Z is gas compressibility coefficient; T is gas temperature, K; P is absolute gas pressure, MPa; P_0 is standard pressure, $P_0 = 0{,}1$ MPa; d is pipe inner diameter, m.

4. Discussion of results

The calculation of the recommended flow rate of the CES for ensuring the well No.514 operation using the CLC technology was carried out according to the methodology of Gazprom VNIIGAZ LLC using the software of Vympel LLC. The calculation is presented in Fig.5.

According to the calculation results, the minimum critical flow rate for the CLK was 600 m^3/h. The recommended value for maintenance during operation is 700-750 m^3/h. According to the obtained critical and recommended production rates, the good operation mode should be maintained according to these parameters in order to remove the liquid phase from the bottom of the well.

In December 2013, well No.514 was put into operation and is currently being stably operated at UKPG-5. For all the time, there was not a single case of good shutdown due to the accumulation of liquid at the bottom and a decrease in gas production. Water removal takes place automatically through the central elevator column under the control of a technological complex for monitoring and controlling gas well operation modes. As of October 1, 2019, the cumulative gas production from well No.514 after KLK equipment, according to operational reports, was 89.8 million m^3.

To monitor the operating mode in real-time, the dynamics of the values of the flow rate and thermobaric parameters were transferred to the AWPP and to the information and control system of the remote control (IMS DU) of Gazprom Dobycha Urengoy LLC. Table 4 presents the average operating parameters of well No.514 for 2014-2019.

To ensure a non-hydrate mode of operation, a hydrate formation inhibitor (methanol) is provided on the CES line and

TABLE 4. THE AVERAGE OPERATING PARAMETERS OF WELL NO. 514 FOR 2014-2019

Parameter	2014	2015	2016	2017	2018	2019
Wellhead pressure, MPa	1.29	1.19	1.18	1.12	1.02	0.91
Well production, thousand m^3/day	52.9	70.6	67.9	65.3	68.9	80.6
CES gas production rate, thousand m^3/day	18.4	18.6	18.5	18.4	15.4	15.3
CTA gas rate, thousand m^3/day	34.5	52.0	49.4	46.9	53.5	65.3
The gas flow rate in the CES, m/s	8.1	9.0	9.0	9.5	9.0	9.6
The gas flow rate in the CTA, m/s	2.1	3.9	4.2	3.4	4.3	4.9
Position RUD-02 MKP,% open	16.2	24.3	22.6	22.7	33.4	27.4
Fluid flow rate, kg/h	36.7	25.8	44.8	55.5	75.7	25.0

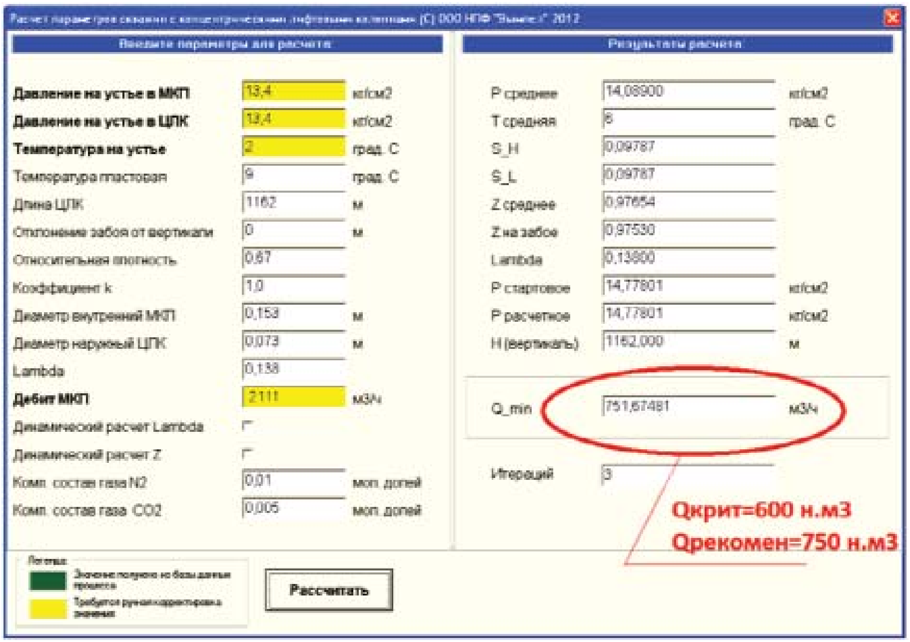

Fig.5 Calculation of the critical rate in the program of LLC NPF Vympel

annular space (CTA). The KLK control complex includes a two-phase DFR-01 flow meter, a hyper-flow gas flow meter, a RUD-02 regulating device for the flow rate of a gas well, an SPI-02 inhibitor supply system.

When developing reservoirs for the depletion of reservoir energy, bottomhole pressures in wells gradually decrease, which leads to a decrease in gas flow density. Thus, with a decrease in the bottom-hole pressure, the minimum required gas velocity for liquid removal increases due to a change in gas density.

At the beginning of 2018, the minimum required gas velocity for the complete and continuous removal of fluid from the bottom of well No.514 is already 5.1 m/s, which is 86% lower than the actual gas velocity in the CES. In order to optimize the technological mode of operation of well No. 514 in March 2018, the calculation of the optimal parameters of good operation was performed. The minimum required gas production rate for the CES was 630 m^3/hour (15.1 thousand m^3/day). Since April 3, 2018, the "set point" of gas production by the Central Control Commission has been gradually reduced from 750 m^3/h to 630 m^3/hour.

5. Conclusions

Thus, it is clear that the innovative technology of good exploitation by KLK avoids closing the well and its subsequent repair in order to eliminate accumulation of liquid at the bottom, and the calculation algorithm allows you to calculate the critical and recommended flow rates that are constantly maintained in automatic mode, which ensure the removal of the liquid phase by the flowing gas.

The proposed technology can be applied to the deposits of domestic and foreign complicated funds (active destruction of the face with the accumulation of liquid), after determining the key operating parameters using the software package.

As a result of the adjustment, at almost identical wellhead pressures, the total average gas production rate increased by 19%, from 62 to 74 thousand m^3/day. Thus, monitoring of the good operation parameters and timely adjustment of the algorithm of the CLC control complex operation allowed optimizing the technological mode of the well. This optimization will continue to be applied as reservoir pressure decreases.

Finally, the introduction of concentric lift technology ensured the stable operation of well No.514 without technological purges. The CLC well monitoring and control complex ensured the reliable operation of the low-production gas well of the Cenomanian deposits of UOGCF in conditions of flooding with condensation water. Reconstruction of gas wells without jamming and their further exploitation by concentric lift columns will ensure efficient gas production from the Cenomanian reservoir at the late and final stages of development.

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