Gas production technologies on gas fields at final stage of development

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Abstract. About 80% of produced natural gas in Russia is taken from Cenomanian gas deposits of Western Siberia. For a long time, the main volume of gas production was selected on the largest unique deposits in the region - Medvezhye, Urengoyskoye, Yamburgskoye. Currently, the development of Cenomanian deposits of these fields has approached the final stage, and the production of initial balance reserves has exceeded 80 percent threshold. It is known that during gas sampling of more than 80-85%, there is a significant decrease in reservoir pressure, and further extraction of the remaining reserves on condition of their main transportation becomes economically inefficient due to the sharply increasing cost of the extracted products. Residual gas reserves of such deposits are not profitable for production, but with deep compression some of them can be extracted. This part is called "low-pressure gas" in Russian terminology. The assessment has shown that reaching an 85 percent production threshold of balance reserves of Cenomanian deposits, only on Medvezhye, Urengoy and Yamburg fields, there will be at least 1 trillion 700 billion cubic meters of gas, of which more than 600 billion cubic meters is "low-pressure gas". The experience of cost-effective extraction of such reserves is currently lacking. The high degree of infrastructure development and the importance of socio-economic factors require the introduction of new technical solutions to extend the development and increase the final gas recovery of these fields. Today, within the walls of research and design institutes dealing with the problems of developing Cenomanian gas deposits, the tasks are solved to create new and improve already approved technological approaches for the development of "low-pressure gas" deposits. In this article, an attempt is made to define "low-pressure gas", to estimate its volumes for currently developed Cenomanian gas deposits of Yamal-Nenets Autonomous District and to give a brief description of proven and promising technical solutions for the well operation at the final stage of development.

1. Introduction

Industrial extraction of Cenomanian gas began in 1972 with the commissioning of Medvezhye field, the first in Yamal-Nenets Autonomous District. Later in 1978, Cenomanian deposit of Urengoy field, the largest in terms of gas reserves in Russia, was introduced into development. In 1986 Yamburgskoye field in Tazovsky Peninsula was put into operation. As a result, in 1992, gas production from Cenomanian deposits reached its historic maximum and amounted to 511 billion m³, of which 427 billion m³ or 84 percent accounted for three above-mentioned fields.

In the following years, 10 larger fields were put into operation. Among the developed Cenomanian
deposits before 2011, it is also worth noting about Zapolyarnoye field, which began production in 2001, and in 2010 this field accounts for about 24% of annual Cenomanian gas production.

Subsequent commissioning of smaller gas reserves since 1992, allowed one to retain production in the range of 457-497 billion m$^3$. However, as a result of natural depletion of reservoir energy and economic reasons, annual withdrawals gradually decreased to 431 billion m$^3$ in 2010, which is about 80% of the total production in Russia.

It is known that during gas withdrawal of more than 80-85 percent, there is a significant decrease in reservoir pressure, and further extraction of the remaining reserves, provided that they are transported by trunk gas pipeline, becomes economically inefficient due to the sharply increasing production cost. The residual gas reserves of such deposits, which are not profitable for production, but with deep compression can still be extracted, are called low-pressure ones. It should be noted that in the official regulatory and legal documents, the term "low-pressure gas" is missing. Further, in this article, the term "low-pressure gas" will mean 35% of the remaining gas reserves of Cenomanian deposits, when they are produced by 85% of the initial balance. The remaining 65% of gas in the production of Cenomanian deposits of 85% will be considered impossible to extract for technical reasons.

2. Results and Discussion

Production of "low-pressure gas" is considered to be possible by existing technologies and techniques, but is unprofitable or low-cost. In general, it should be understood that these figures will be different for different fields, but for an approximate calculation of the volumes of "low-pressure gas" for senoman deposits, conventionally accepted figures will be used in this work.

In table 1, there is column number 5, which presents the residual reserves when the gas recovery factor (GRF) is at the level of 0.85 d.units. Only reaching this gas yield, 35% of the remaining reserves will be considered "low-pressure" and unprofitable for production; other 65% can not be extracted at all with existing production technologies. Totally according to the deposits presented in table 1, such gas is expected to be about 1 trillion 140 billion m$^3$ (column 6, table 1). This amount of reserves is comparable to the reserves of Yen-Yakhinskoye gas field, which is a unique deposit in Russia. In this regard, the creation of new technological approaches to develop Cenomanian gas deposits of "low-pressure gas" will have a significant impact on the development of not only the domestic gas industry, but the entire economy of the country.

As can be seen from table 1, the most depleted out of developed Cenomanian deposits of large gas fields in Western Siberia are currently Vyngapurovskoye, Medvezhye, Yamburgskoye and Urengoyskoye. The development of these fields is accompanied by a decrease in reservoir pressure, lifting of gas-water contact and flooding the bottom-hole zone of wells with condensation and formation water.

Reducing reservoir pressure and flow rate worsen the conditions for removal of liquid and mechanical impurities from the bottom wells. Accumulation of water leads to an increase in filtration resistance, a further decrease in productivity and eventually to spontaneous shutdown of wells or so-called "self-killing". Without carrying out various geological and technical measures aimed at maintaining the operation mode of "self-killing" wells, the volume of low-pressure gas reserves will increase. Let us consider in detail approved and perspective solutions allowing one to operate wells at the final stage of development of Cenomanian deposits of "low-pressure gas".

Geological and technical measures to maintain the operating mode of self-killing wells include:
- carrying out well workover, including anchoring the bottomhole formation zone and water shut-off works;
- periodic blowing of wells with the release of gas into the atmosphere;
- treatment of bore holes with solid and liquid surfactants;
- replacement of tubing on pipes of smaller diameter;
- application of free piston;
- use of concentric lift;
- cyclic injection of dry gas into the annulus;
application of packaged compressor plants.

| Fields             | Initial gas reserves, billion m³ | Accumulated gas offtake at the beginning of 2011, billion m³ | Current gas recovery factor, % | Residual reserves at GRF = 0.85, bn m³ | Volume of low-pressure gas, billion m³ |
|--------------------|----------------------------------|-------------------------------------------------------------|--------------------------------|---------------------------------------|---------------------------------------|
| Vyngapurovskoye    | 395                              | 333                                                         | 84,3                           | 59,3                                  | 20,7                                  |
| Medvezhye          | 2347                             | 1855                                                        | 79,0                           | 352,1                                 | 123,2                                 |
| Yamburgskoye       | 3933                             | 3081                                                        | 78,3                           | 590,0                                 | 206,5                                 |
| Urengoyskoye       | 5366                             | 4172                                                        | 77,7                           | 804,9                                 | 281,7                                 |
| Yen-Yakhinskoye    | 1263                             | 858                                                         | 67,9                           | 189,5                                 | 66,3                                  |
| Komsomolskoye      | 778                              | 502                                                         | 64,5                           | 116,7                                 | 40,8                                  |
| West-Tarkosalinskoye | 325                           | 196                                                         | 60,3                           | 48,8                                  | 17,1                                  |
| Juibileynoye       | 522                              | 286                                                         | 54,8                           | 78,3                                  | 27,4                                  |
| North-Urengoyskoye | 586                              | 311                                                         | 53,1                           | 87,9                                  | 30,8                                  |
| Yamsoveyskoye      | 560                              | 276                                                         | 49,3                           | 84,0                                  | 29,4                                  |
| Gubkinskoye        | 399                              | 166                                                         | 41,6                           | 59,9                                  | 20,9                                  |
| East-Tarkosalinskoye | 295                           | 103                                                         | 34,9                           | 44,3                                  | 15,5                                  |
| Vyngayakhinskoye   | 122                              | 36                                                          | 29,5                           | 18,3                                  | 6,4                                   |
| Zapolyarnoye       | 2825                             | 786                                                         | 27,8                           | 423,8                                 | 148,3                                 |
| Ety-Purovskoye     | 315                              | 85                                                          | 27,0                           | 47,3                                  | 16,5                                  |
| Pestsovoye         | 825                              | 132                                                         | 16,0                           | 123,8                                 | 43,3                                  |
| South-Russian      | 673                              | 65                                                          | 9,7                            | 101,0                                 | 35,3                                  |
| Yurkharovskoye     | 119                              | 4,1                                                         | 3,4                            | 17,9                                  | 6,2                                   |
| Novogodnye         | 9,3                              | 0,2                                                         | 2,2                            | 1,4                                   | 0,5                                   |
| Muravlenkovskoye   | 54,4                             | 1,1                                                         | 2,0                            | 8,2                                   | 2,9                                   |
| Total              | 21711,7                          | 13248,4                                                     | Average 61,0                    | 3256,8                                 | 1139,9                                 |

**Treatment of production wells with surfactant compounds**

In Medvezhye field, three types of technologies for removing fluid from the well with the use of surfactants are used to intensify the production of gas: treatment of downhole with solid surfactants, treatment of bottomhole formation zone (BFZ) with liquid surfactants and treatment of the liquid surfactant with subsequent displacement of methanol into the formation.

When surfactant interacts with water, a stable foam is formed, which is a dispersed system consisting of gas bubble cells. Separating gas bubbles liquid films form a continuous film frame, which is the basis of the foam. To remove the foamed liquid, the well is simply put into operation, or first worked on a "torch" for 12 hours and then put into operation. In the case of methanol injection, the well is worked on the "torch", removing the foamed liquid, then inject and pump into the reservoir with 3-5 m³ of methanol, and then the well is put into operation. The average effect of treatment with
liquid surfactants is 105 days, in contrast to solid surfactants, from which the effect is an average of only 10 days.

**Operation of wells with the use of concentric lift**

The technology of operation of wells on concentric lift columns is a process in which the gas, coming from the reservoir to the bore hole, is divided into two streams rising in parallel along the channels formed by two columns of pipes – the central lift column (CLK) and the main lift column (MLC), concentrically placed one in the other and communicating in the lower part with each other. Gas flows after lifting to the wellhead are connected and enter into one gas-discharge manifold. Under conditions complicated by the inflow of liquid into the well and / or destruction of the bottomhole zone of the productive formation, gas withdrawal from the well is limited by a constant or adjustable nozzle installed on the flowline from the well and / or back pressure in the gas collection manifold. "VNIIGAZ" has developed a technology of automatic control of well operation using concentric elevator columns and the first wellhead gas-pneumatic complex to control the operating mode of the well. The technology allows automatically maintaining in CLC the value of gas production rate, which exceeds by 10-20% the minimum value of the gas flow necessary for removal of liquid from the bottom along CLC.

The use of this technology is also possible in wells characterized by intense sand development, but in these cases work is needed to fasten bottom hole formation zone (BFZ) during the well casing in workover.

On two wells of Medvezhye field, tests of technology and the equipment for operation of the flooded wells on concentric lift columns were carried out. In general, the results of the tests on one well are recognized as positive, on other well the additional analysis of the obtained data is required to carry out. As a positive point, it is necessary to note the reduction in the number of blowdowns of the wellbore with the release of gas into the atmosphere. Among the shortcomings, there is a large amount of maintenance work compared to other wells and a reduction in the well production rate with partial overlapping of the annular space to ensure the removal of liquid through the central lift column.

**Well operation with free piston usage**

A free piston functions cyclically in the well, which works, stops. During the stop, when the plunger is at the bottom, the pressure of gas increases in the annulus, while the liquid in the well has almost accumulated at the final stage of the gushing period. The fluid accumulates in the tubing shoe, and the plunger descends through its column to the shock absorber spring, where it remains for the entire period of pressure build-up. Gas pressure in the annulus depends on the duration of well stopping, reservoir pressure and reservoir permeability. When the pressure in the annulus sufficiently increases, the drive valve will open and the well will start to work in the flow line.

The advantage of the technology is: reducing the number of blowing of bore hole with the release of gas into the atmosphere; the possibility of using columns Du = 168 mm in elevator without reducing the flow rate of the well; installation of free piston equipment is performed without killing the well for a period not exceeding 30 minutes; low cost of equipment. The disadvantages of the technology are a large amount of maintenance work compared to other wells and the inability to use imported production in the wells equipped with Christmas tree assembly.

**The use of wellhead compressor units**

To regulate the technological mode of wells regardless of the pressure at the inlet to the booster compressor stations (BCS), a promising technological solution will be a modular compressor unit (MCU), the introduction of which will raise the inlet pressure to the BCS and thereby extend the work of the fields as a whole. At the same time, it will be possible to regulate the wells flexibly, resulting in idle wells being put into operation, gas production will increase, and drainage of the reservoir will improve. Wells will work regardless of the pressure at the entrance to the BCS.

This technology will allow continuing production of low-pressure gas and achieving maximum gas recovery of the deposit. MKU will provide operation of wells up to wellhead pressure of 0.15 MPa.

3. Conclusion
Unique Medvezhye, Urengoyskoye and Yamburgskoye fields produced on average more than 80%, and the gas withdrawal decreased by almost 80%. With the use of traditional technologies after the completion of the development in Cenomanian deposits, only these three fields will yield at least 1 trillion 700 billion m$^3$ of gas, of which more than 600 billion m$^3$ will be "low-pressure gas".

The main problems in the fields that are at the final stage of development are: reduction of the production capabilities of the formation and productivity of bottom hole well zones; deposit inundation and intensive water and sand showings during well operation; growth of self-killing wells; physical and moral wear and tear of equipment, which requires constant updating and accordingly significant volumes of capital investments in the reconstruction and technical re-equipment of production facilities.

The most promising technical solutions for the operation of wells at the final stage of development are the injection of surfactants on the bottom, the use of free piston and concentric lift, cyclic injection of dry gas into the annulus and the use of modular compressor systems that allows one to adjust the technological mode of operation of wells regardless of the pressure at the entrance to the BCS.

References
[1] Baturin Y E 2010 Bazhen without benefits so it will remain. Oil and Gas vertical 23-24 12-16
[2] Deliya S V, Drandusov K A, Karpov V B and Mamaev D.A. 2015 RITEK: Prospecting experience, prospecting, reserves calculation and deposit developments of bazhen formation/ Subsurface management XXI century 1 (51) 80-83
[3] Korovin K V, Pecherin T N 2016 Analysis of operating results from the bazhenov formation of deposits of the territory of KHMAO-Yugra. International research magazine 12 (54) 91-94
[4] Nesterov I I, Brekhuntsov A M  2010 Oil bituminous clay, siliceous clay and carbonate-silica-clay rocks Vestnik CKR Rosnedra 6 3–16
[5] Sarancha A V., Sarancha I S 2014 Analysis of the bazhen formation development at Ulyanovskoe field. Academic magazine of West Siberia10-1 128-129
[6] Sarancha A V, Garina V V, Mitrofanov D A and Levitina E E 2015 Pilot Development Planning’s results of bazhenformation of Zapadno-Sakhalinskoe field. Fundamental researches. № 2-14. 3052-3055
[7] Sarancha A V, Mitrofanov D A, Sarancha I S and Ovezova S M 2015 Bazhen formation development of Ay-Pimskoye field// Current problems of science and education. 1-1 204-208
[8] Tolstolytkin I P 2012 Oil reserves use at the fields of KHMAO-Yugra. Science and FEC 5. 4. 26-28
[9] Shandyrin A N, Shpurov I V, Bratkova V G 2015 State and prospects of shale oil deposits development. Subsurface management of XXI century. 1 (51) 52-63