

## The Features of Blowout Prevention Equipment for Drilling of the Bazhenov Formation

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### **Abstract**

The article presents basic information about the Bazhenov formation, as well as its features and differences from other formations, complicating factors in the construction of wells. The experience on the development of a Suite of such companies as: "Surgutneftegas" Bitteschon and the Ulyanovsk fields and "Salym petroleum development" at the West Salym field. The characteristic of the blowout equipment for drilling at abnormally high reservoir pressure is given, the characteristic of the rotating preventer is given, the statistics of wear of the equipment Park is presented. The complex experience of drilling shale oil in the United States using coiled tubing and drilling at negative differential pressure is described, positive results of this method are presented. Leaders in the development of Bazhenov formation in Russia and shale oil in America are presented. The article describes the blowout equipment for coiled tubing installation, as well as materials used for seals of preventers. Conclusions are drawn about the relevance and problems of the Bazhenov formation development in Russia.

**Keywords:** *Bazhenov Formation; Abnormally high reservoir pressure; Blowout equipment; Preventer; Shale oil; Drilling; Coiled tubing installation; Well.*

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## **1. Introduction**

According to various estimates, about 70% of the world's oil shale reserves are concentrated in the United States - mainly in the Bakken formation, as well as in the Eagle Fort (Texas) and Bone Spring (New Mexico) fields. Russia possesses 7% of the world's reserves. According to the US Energy Information Administration, Russian resources, due to drilling and production conditions, are the most promising for development. The largest part of Russia's oil shale is concentrated in the Bazhenov suite of deposits [1].

According to the results of the EIA assessment, out of 345 billion barrels of shale oil of the world, 22% (10.3 billion tons) are concentrated in the Bazhenov Formation [2]. This article also identifies the risk factors used for shale gas and shale oil reservoirs in assessing the resources by EIA/ARI: "game success factor" is 100%, "promising success factor" is 50% [2].

The Bazhenov Formation is a group of oil source rocks (suite) identified by F.G. Gurari in 1959 on an area of about one million square kilometers in Western Siberia. It has been formed by seabed sedimentary rocks about 145 million years ago, is characterized by a complex geological structure and lithological features, analytical data of modern studies prove its heterogeneity [3].

The first Bazhenov oil was produced in 1968, in the exploration well 12P of the Salym field at a depth of 2840 m. During drilling, carbonated oil was released with a flow rate of about 700 tons / day. The fountain caused a fire, but was liquidated, after which gushing oil inflows from this suite were obtained at three more fields [4].

The total geological resources of Bazhenov oil are estimated at 0.8-2.1 trillion tons. The formation lies at a depth of two to three kilometers and has a small thickness: usually twenty to thirty meters, while it is an unconventional and difficult to recover object, which has been studied for more than 60 years [5]. The prospects for the oil and gas content of the formation are still questionable, since it is impossible to fully study this topic, and methods for assessing

reserves, resources and parameters based on the results of geophysical tests have not been determined.

The main differences between the rocks of the Bazhenov Formation from the lower and overlying sedimentary strata of terrigenous genesis (rocks):

1. Abnormally high concentrations of organic substances, uranium, silicon dioxide, phosphorus (V) oxide, rare earth elements and a number of non-ferrous metals.
2. With a relatively small thickness (25 ... 35 m), it is characterized by sustained distribution over a large area.
3. Small thicknesses and long sedimentation time (up to 10-12 million years) indicate vanishingly low rates of sedimentation.
4. The overwhelming predominance of biogenic components in the rock-forming constituents.
5. The abnormally high reservoir pressure.
6. Presence of interlayers of clays and shales that plug hydraulic fractures.
7. The size of oil-containing pores is too small, extracting oil from such pores needs higher pressure gradients; in practice it is unrealistic [6].

These features have become the reason for the main complicating factors in the construction of wells, the following ones standing out:

- abnormally high reservoir pressure, which can reach 52 MPa, at a reservoir depth of 2800 - 2900 m;
- coefficient of abnormality in the range: 1.31-1.78;
- high fracturing;
- abnormally high electrical resistivity;
- weak stability of rocks;
- the volumetric content of hydrogen sulfide more than 6%;
- high reservoir temperature of the well [7].

Due to these factors and features, a number of problems arise: forecasting the top of the seam while drilling, high wear of underground equipment, the possibility of emissions and open fountains.

## 2. Methods and theoretical background

The authors analyzed the Russian experience of drilling the Bazhenov formation. OJSC "Surgutneftegas" has discovered a promising zone of distribution of Bazhenov rocks of about 75 thousand km<sup>2</sup> in the Khanty-Mansiysk Autonomous Area. Within this area, the development of the suite is carried out in the most productive sections of 14 fields, where about 140 wells were operated. One of these fields, Bittenskoye, which was discovered in 1989 by drilling an exploratory well and drilled by the Pravdinskaya oil exploration expedition of Glavtyumengeologiya, was commissioned in May 1999. After the opening of the Bazhenov deposits at a depth of 2860 m, drilling of the well was stopped at a depth of 2910 m. The well performance during drilling was as follows: formation temperature of the well – 95 to 100°C, formation pressure – 38 to 50 MPa, coefficient of anomalous formation pressure - 1.32 - 1.75, the total thickness of the fractured zones - 4.8 m, fracture intensity in the producing zones - 350 m<sup>-1</sup>, the permeability of the producing zones - 1.5x10<sup>-3</sup> μm<sup>2</sup> [7]. The drilling was performed using blowout equipment with four preventers and a weighted water-based drilling mud containing clay, carboxymethyl cellulose KMTs-500-700, NaCl or KCl salts to ensure the stability of the borehole walls when drilling rocks of different properties [8]. Since there is a likelihood of formation manifestation, the opening is performed at a large excess of pressure, which can lead to hydraulic fracturing of the formation and the withdrawal of a large amount of solution into it, now new technologies are used: drilling a well with balanced pressure on the formation under conditions of abnormally high formation pressures based on the operational determination of reservoir parameters; opening of a productive formation using drilling mud treated with chemical reagents that prevent a decrease in the natural permeability of the formation. Also, for drilling the Bazhenov formation in Russia, special devices are used in the arrangement of the bottom of the drill string, such as an oscillator system, a centralizer, a calibrator, a jar, a smaller diameter drilling tool.

Interesting is the experience of Surgutneftegaz OJSC in the development of the Ulyanovsk field, discovered in 1997 and commissioned in 2000, with the main task of the pilot development being to validate the technology of opening the formation under depression with horizontal wells using a coiled tubing unit. After opening the formation deposits at a depth of 2840 m, drilling of the well was stopped at a depth of 2900 m. The well performance during drilling was as follows: formation temperature of the well – 95 to 102°C, formation pressure – 38 to 50 MPa, coefficient of formation pressure abnormality - 1.31 to 1.78, fracture intensity in the producing zones - 78, the total thickness of fractured zones - 3.9 m, the is 350 m<sup>-1</sup>, the permeability of the producing zones - 1.5x10<sup>-3</sup> μm<sup>2</sup>. The formation was opened with minimal repression using biopolymer drilling mud. The chosen technology of opening the deposit provoked the manifestation of complications during drilling, especially when driving the bottom part of the formation. Consequently, the full opening of Bazhenov was carried out only in two wells [7].

At present, shale oil is produced on the largest scale in Russia by Salym Petroleum Development. More than 1,100 exploration and production wells have been drilled in the Salym group of fields. Before drilling the West Salym field, discovered in 1987, a geological project was prepared for the development of horizontal wells. The first well was commissioned in 1988. In the process of drilling, telemetry tracking and geophysical survey of the well took place. The horizontal section was drilled with a 152.4 mm PDC bit, cuttings were sampled at an interval of 10 m, four preventers were included in the blowout equipment, and the drilling was carried out with weighted mud. Round-the-clock monitoring of the drilling process, together with the analysis of all incoming geological and geophysical data, made it possible to make operational decisions on adjusting the drilling trajectory and prevent accidents associated with abnormally high reservoir pressure. In this field, a well completed with liner cementation was applied, and in another well, a completion by running a slotted screen without cementation was applied [9].

### 3. Results and discussion

Summarizing the experience of drilling the Bazhenov formation, the authors formulated specific requirements for equipment for this process:

To prevent blowouts and uncontrolled flows in wells, blowout equipment is used. It includes preventers, an adapter spool, a flow cross, a detachable trough, manifolds, manifold and preventer control stations [10]. At the wellhead, in the case of drilling the Bazhenov formation, four preventers are installed, including one shear ram preventer and one annular preventer, a rotating BOP is currently being installed, it is installed above the BOP stack instead of the detachable trough.

A rotating BOP is installed to permanently seal the wellhead, around the kelly hub, drill pipe, and tool joint. If it is there, you can walk, turn and rotate the tool, lift the drill pipes. The main assembly is a rubber cell specially shaped to allow the tool to be pulled up or down through the seal. This preventer allows drilling with backwash, blowing the bottom hole with a gaseous agent or aerated solution, with an equilibrium system of hydrostatic pressure on the formation, opening and testing high pressure formations [11]. Rotating preventers have not found such widespread use in Russian drilling companies as annular ones, despite the fact that the role of a rotating preventer is much more important when the tool is in the well, so their development, modernization has been suspended, currently two types and four standard sizes being produced.

In wells with the expected wellhead pressure exceeding 70 MPa, a manifold with three adjustable chokes is installed: two with remote control and one with manual control. Pressure gauges installed on choke and kill manifolds must have an upper limit of the measurement range 30% higher than the pressure of joint casing pressure testing and BOP equipment [12].

When opening layers with abnormal pressure, horizons containing hydrogen sulfide, three valves are installed on the drilling rig. One ball valve between the working tube and the swivel, the second - between the working tube and its safety sub, the third is a spare one. All ball valves are open. In addition to ball valves, there are two check valves on the rig with a device

to set them in the open position. One valve is working, the second is standby. Before and after the opening of formations with abnormal pressure during the resumption of well flushing after round-trip operations, geophysical surveys, workover and downtime after the restoration of circulation, the density, viscosity and gas content of the drilling mud are to be monitored [12].

In drilling rigs of domestic production, imported equipment is contained in all components and accounts for about 45% of the cost of the entire drilling rig. In Russia, only about 30% of equipment is less than 10 years old, another 50% is older than 20 years (equipment wear in general is up to 80%), it also has a relatively low quality of materials and components [13], such equipment is not suitable for drilling Bazhenov formation,

Similar wells have been drilled in the United States using a combined coiled tubing unit and negative differential pressure drilling, which provides a highly efficient process. This method is carried out in several stages. In the first stage, a well is drilled to the reservoir using a conventional drilling rig, or an old wellbore is prepared. At the second stage, opening and drilling of the wellbore is carried out within the producing layer by an underbalanced method using a coiled tubing complex [14].

The essence of the underbalanced drilling method is that for flushing the bottomhole, a drilling mud of such density is selected so that the total pressure it creates on the bottomhole is less than the formation pressure. In this case, the opening of the formation is accompanied by the inflow of formation fluid into the well. However, the implementation of these terms of reservoir penetration is only possible with reliable wellhead and blowout preventer equipment capable of sealing the wellhead while drilling in the productive formation and withstanding the arising pressure drops between the wellbore and the earth surface (meaning systems of stationary and rotating preventers). Foreign experience has shown that the use of this method yields positive results:

- reduction of contamination of the productive formation, as well as the bottomhole zone;
- a significant increase in the productivity of oil and gas reservoirs;
- reduction of costs and time for the well development;
- increasing the recovery factor of the reservoir products;
- increasing the rate of penetration and resource of rock cutting tools;
- prevention of lost circulation of drilling mud;
- reducing the likelihood of sidewall sticking [15].

Leaders in shale oil drilling and production are: Occidental Petroleum in the Perm formation, Whiting Petroleum in the Bakken formation in North Dakota, Anadarko Petroleum in the Appalachian region, the southern United States and the Rocky Mountains.

High equipment requirements are fundamental for drilling abroad. In the piping of blowout preventers during coiled tubing drilling, dual, triple, quadruple ram BOPs are used, designed for an operating pressure of 35/70/105 MPa. BOP seals are made of polyphenylene sulfide and metal filled with PTFE-4 with 15% fiberglass, or polyurethane composition.

#### **4. Conclusion**

The conditions for drilling the Bazhenov formation are much harsher than when drilling conventional formations, since there almost always appears abnormal pressure, which means the likelihood of gushing, there is also a high formation temperature of the well, which has a negative effect on the equipment as a whole. During the development of this formation, a reliable recovery method has not been found, since the cracks are clogged and the inflow decreases.

For the development of the Bazhenov Formation, the equipment must be in proper condition and constantly monitored. Due to the fact that earlier equipment was purchased more often abroad, now there is a lack of repair component parts, which cannot always be manufactured in Russia. The strategy of import substitution of drilling equipment contributes to the development of domestic production bases through investment programs, but, unfortunately, this is not enough, since the industry's dependence on the import of specialized technologies and high-tech products is great.

At the moment, government support is needed for domestic development, since American shale production technologies at Bazhen are not efficient enough. The development should be based on the experience of Russian and foreign companies in order to find new methods of drilling and well development, as well as ways to assess reserves, technology and resources for the commercial development of hydrocarbons in this formation. Now companies themselves are investing in this, and with the current taxation it is not profitable.

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