LHG FOR HF

RESERVOIR PRESSURE MAINTENANCE

FROM INSIGHT TO WELL

BUSINESS MAGAZINE

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SIMPLE ABOUT SERIOUS

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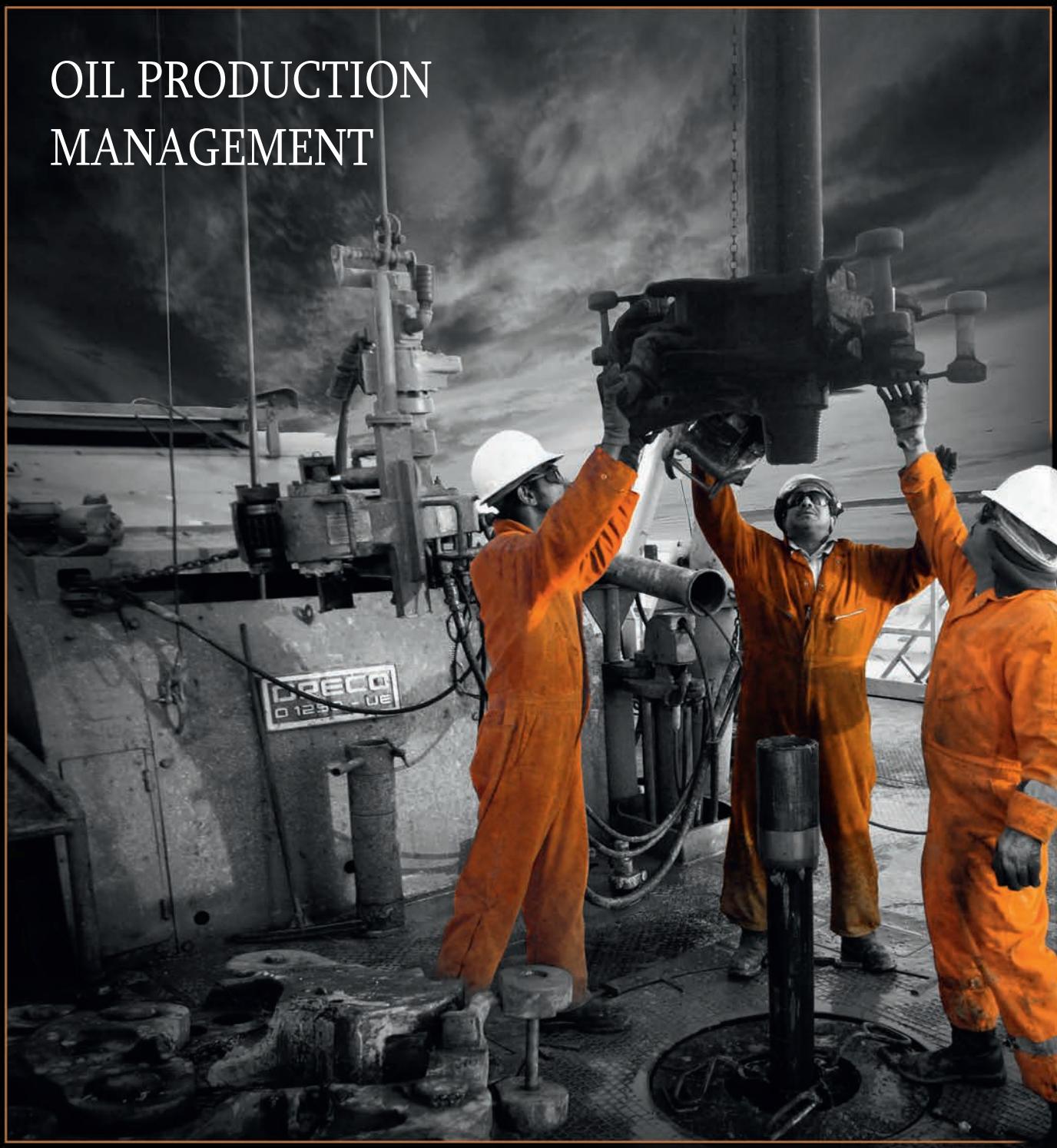
6 [90] 2019

OIL PRODUCTION MANAGEMENT



MAIN ACTIVITIES

EXPLORATIVE AND OPERATIONAL DRILLING OF OIL AND GAS WELLS, INCLUDING HORIZONTAL DRILLING

DEVELOPMENT AND MAINTENANCE OF DRILLING FLUIDS, SELECTION OF FORMULATIONS

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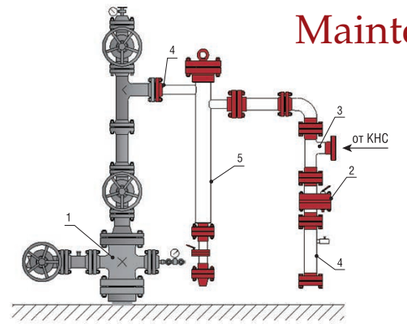

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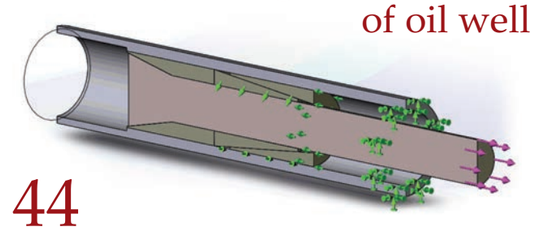

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OIL AND GAS INDUSTRY EPOCHS

284 years ago

In 1735, mining began in the oil fields of France.

155 years ago

In 1864, the first oil well was drilled in the northern Caucasus near Anapa.

154 years ago

In 1865 on the left bank of the Kudako River works began with the use of mechanical percussion drilling driven by a steam traction engine and with the placement of metal casing into oil wells.

133 years ago

In 1886, the first gas pipeline was laid between Pennsylvania and New York: from the town of Nain to the town of Buffalo.

123 years ago

In 1896, the process of air oxidation of heavy residues from the distillation of oil at high temperatures was developed. As a result, oil bitumen was obtained, used for covering roads.

108 years ago

In 1911, the United States passed a law on the demonopolization of the oil holding Standard Oil, which resulted in the creation of five companies: Standard Oil of New Jersey, Standard Oil of New York, Standard Oil of California, Standard Oil of Indiana and Standard Oil of Ohio.

101 years ago

In 1918, the Oil Commissariat was abolished, and the Main Oil Committee was established to regulate and control the oil industry and petroleum products trade.

96 years ago

In 1923, a turbo-drill was used for the first time for drilling wells. The first industrial design of the equipment was invented and manufactured in the USSR.

92 years ago

In 1927, the largest oil field was discovered in Iran in the province of Kirkuk.

81 years ago

In 1938, as a result of the nationalization of the oil industry in Mexico, the state-owned company Petroleos Mexicanos was formed.

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Rosneft has ruled out the construction project Eastern petrochemical complex from their investment plans


Oil refining at Russian refineries twice more profitable than in Europe

LOW INTEREST IN HIGH-MARGIN PRODUCTIONS OR WHY BUSINESS IS RELUCTANT TO EARN

Anna Pavlikhina

On 14 May 2019, Rosneft excluded the Eastern Petrochemical Complex construction project from its investment plans. According to the company's management, the project became unprofitable due to the recent tax maneuver. The EPCC project envisaged the construction of an oil refining and petrochemical complex in Primorsky Krai.

As usual, Rosneft was counting on government support which was granted. However, it was made clear that "you have to pay cash on the barrelhead", meaning support would be given as soon as the project started.

On its part, the Ministry of Finance objects to the fact that its tax maneuver was to blame for the closure of the project. Since the beginning of 2019, Russia has introduced special measures to support oil refineries in the form of negative excise duties on crude oil refundable from the federal budget. According to data released from the Ministry it follows that the implementation of the project in terms of the tax maneuver would increase the efficiency of the first stage by more than 30%.

While the ministries and companies are busy justifying their own viewpoints, foreign oil producers are moving to higher levels of processing and developing petrochemical production. Director of the Institute for Globalization Problems, M. Delyagin, was quoted as saying: “if before it was possible to sell raw materials and not think about anything, today there is a global trend: companies are moving to more complex, but more profitable production – petrochemical production, oil refining and natural gas chemistry.” He provides the example of Saudi Aramco that receives more than 40% of its revenue from oil and gas chemistry. Why doesn’t business in Russia see the potential in the production of high-margin products?

Some experts (although you do not need to be one) claim that the blame lies in the general instability casting a shadow on the country's economy, including the oil and gas sector, and this negatively affects the investment climate. Investments in oil refining and petrochemicals translate into large sums of money and long-term revenue.


Most refineries in the last 30 years have built by private companies


EPCP, contributing to the development subsidized region

Naturally, in conditions of difficult forecasting and fragile guarantees, this sector of the economy appears extremely unattractive.

Others support vertically integrated oil companies and their negative stance on the tax maneuver, confirming that starting from January 2019 Russian oil refineries have been generating losses. Independent companies, without government influence, disagree with them. For example, a LUKOIL representative said that crude oil refining at Russian oil refineries is almost twice more profitable than in Europe (LUKOIL owns four oil refineries in Russia and three oil refineries in Europe). According to the company's estimates, from January – April 2019, the refining margin in Russia for oil refineries at LUKOIL was $9 per barrel, and in Europe it was $5. And despite the tax maneuver, LUKOIL did not curtail any of its oil refining projects.

And at $100 per barrel, vertically integrated oil companies were not good examples of incentives for the petrochemical industry. Over the past thirty years, no more than a dozen oil refineries have been built, a large proportion of which is accounted for by private companies, and not by state-owned vertically integrated companies. Expecting that this would happen at the current oil price would be naive. Or would it? After all, it is the low cost of oil that should encourage the processing of crude oil into more expensive products. One way or another, there is no progress in the petrochemical market on the part of production companies.

Many renowned experts have put forward the view that the tax policy of the state prevents oil-producing companies from pursuing high-margin industries. The author of the article believes that such excuses (calling things by their proper names) are explained by the unwillingness to invest in long-term projects. This may be partly due to the desire to get quicker profits and also a mistrust of the future (under conditions of uncertainty it is safer to withdraw money to foreign accounts than to invest in unpredictable industries). Nevertheless, whatever the reason, the plain greed of companies, vague prospects or inept policies in a country where business does not want to earn, something is clearly wrong, primarily, in the state management sector.

And in this situation, the government would have had to intervene in order to show its willingness to resolve the controversial issues even if by its own rules. A mere 10 years ago, leading higher education institutions of the Far Eastern Federal District under the auspices of municipalities created several scientific conferences with the agenda “Will Russia lose the Far East”, that being said, the petrochemical complex was not just a project, it was a project contributing to the development of a remote, subsidized region of the Far East.

And, finally, oil companies themselves have to develop petrochemistry and oil refining, as the demand for these products will increase regardless of whether the energy paradigm shifts towards renewable energy sources and other resources or remains reliant on the oil and gas sector. ●

NEW DOCTRINE OF ENERGY SECURITY

Elena Alifirova

President Vladimir Putin approved a new doctrine of energy security of the Russian Federation. The document describes in detail the challenges and threats in the field of energy security. The new doctrine replaced the previous version of 2012. According to the doctrine, the full-scale participation of the Russian Federation in ensuring international energy security is hindered by restrictive sanctions imposed by a number of foreign states on the Russian Federation.

Foreign policy challenges highlighted in the document include a slowdown in global energy demand, increased competition between suppliers and changes in the international legal regulation. In this regard, the document also refers to the growth of LNG production and an increase in the share of renewable energy resources in the global fuel and energy balance.

The external threats to the energy security of the Russian Federation include the use of financial, contractual and international legal mechanisms by foreign countries to the detriment of the Russian Federation, the discrimination of Russian suppliers and the illegal selection of energy resources supplied by Russia. This section also encompasses restricting access for Russian organizations of the fuel and energy sector to modern technologies, equipment and financing.

Among domestic threats and risks, there is a discrepancy between the fuel and energy sector to the needs of the country's development, a decline in the quality of the mineral resource base, an increase in crime in the fuel and energy sector, excessive financial burden on industry enterprises and lack of human resources.

The main ways to overcome these difficulties include improving state management systems; preventing crimes against fuel and energy facilities, maintaining fuel and energy reserves at the required level in the state reserve, developing distributed sources of energy supply; reducing the negative impact of companies on the environment, as well as developing a reasonable level of competition.

There is also the need to counter the discrimination of Russian energy companies and power engineering companies on the world market. Furthermore, it is imperative to support the export of Russian products, technologies and services, as well as international projects implemented with participation of Russian companies. The doctrine envisages strengthening integration with the countries of EAEU and CIS, as well as consolidating partnerships within the framework of BRICS, SCO, GECF and OPEC.

Neftegaz.RU ratings

In May PJSC Rosneft abandoned plans for the construction of the Eastern Petrochemical Company. The project envisaged the construction of an oil refining and petrochemical complex in Primorsky Krai. As part of this project, an advanced development territory was even created, however, the company cited the negative impact of the new approach to project regulation and finally curtailed it. Why do oil companies consider it unprofitable to develop oil refining?

Why do oil companies consider it unprofitable to develop oil refining?

49% Oil refining means long-term revenue as opposed to selling crude oil

34% The government is not so willing to support oil refining projects in the same way it supports mining projects

10% The implementation of the significant tax maneuver in the oil industry makes projects in oil refining sector unprofitable

4% Oil refining is not a direct specialisation, as a result, shifting focus to a secondary activity is associated with difficult cost recovery

3% The freezing of fuel prices makes production unprofitable in contrast to crude oil where the price is regulated by the market

In recent years, about 50 significant amendments have been made to the Tax Code that affect investment projects in the oil refining sector, thereby influencing the price of petrol. Apart from this, there are several other reasons that affect the price of fuel. What should be done by the government and companies in order to make the cost of petrol in Russia proportionate to the infinite oil reserves of the country?

How can fuel prices be reduced?

64% The government should introduce clear rules on the market that allow to forecast the situation

16% It is imperative to modernise oil refineries and focus on increasing the output of light petroleum products

9% It is necessary to implement tax cuts

9% It is necessary to introduce preferential advantages and incentives for Russian companies

2% The government should fix the price artificially

Oil prices
Duty abolition
Presidential elections
Increase in production capacity
Gas wars
Nord Stream
The new head of "Rosneft"
Launch of new production
Stock market crash

Another LNG plant

Arctic LNG-2 and TechnipFMC signed a contract for the construction of an LNG plant with a capacity of 19.8 million tons per year as part of the Arctic LNG-2 project with the first phase planned to be commissioned in 2023.

Arctic LNG 2 involves the construction of three phases for the production of LNG with a capacity of 6.6 million tons per year based on Gravity Based Structures (GBS).

The launch of the second line of the LNG plant is scheduled for 2024, the third – for 2025.

Capital expenditures for the Arctic LNG-2 project are estimated at $10 billion in comparison to $27 billion for the Yamal LNG project, Novatek's first LNG plant. Cost reduction is planned by actively attracting Russian companies to the project implementation.

Unique transformer of the Volga hydroelectric power station

For the first time in Russia, a unique phase-turning transformer has been put into operation by the Volga hydroelectric power station. The unique equipment, made by the joint venture "Power Machines – Toshiba. High-voltage Transformers", is designed to increase the capacity of the power system of the hydroelectric power station.

As part of the modernization, outdated hydroelectric units of the Volga hydroelectric power station are being replaced with new ones. By 2023, the station's capacity should increase to 2,744.5 MW.

Maintaining the status quo will not allow the increase in capacity into the power network to take place. The traditional way of solving the problem was the reconstruction of existing and construction of new grid facilities, but

this requires considerable expenses. The advantages of a phase shifting transformer include the fact that at maximum capacity it allows the redirecting of power generated by the hydroelectric power station from high-loaded lines to less-loaded ones.

The introduction of the phase-shifting transformer into trial operation reduces the cost of connecting the increased capacity of the Volga hydroelectric power station to the power network more than six-fold. The economic effect of this technical solution exceeds 3 billion rubles..

New invention from Sevastopol

Professor I. Shirokov of the Institute of Radio Electronics and Information Security at Sevastopol State University invented a water content meter for petroleum products and presented it at a prestigious international showroom. The device is a pipeline tie-in with a diameter of 100mm and a length of 20 cm.

Knowing the exact water content is crucial in order to determine the price of oil and take measures for its dehydration before refining or add it to the oil product with the aim of improving the parameters of fuel oil combustion in boiler houses. As a result, the durability of equipment increases and harmful emissions into the atmosphere are significantly reduced.

According to the inventor, the meter is based on a new patented method completely different from the existing ones. It is an on-stream device and it determines the water

content almost instantly allowing to control the water content in oil with an accuracy of 0.1%, which is higher than existing meters in the world.

The uniqueness of the meter is that its readings do not depend on the composition of the oil itself. As a rule, the readings of other devices are strictly regulated to a particular type of oil depending on the content of salt and asphaltenes.

The device won the bronze medal at the 22nd Moscow International Salon of Inventions and Innovative Technologies "Archimedes-2019".

NGL: to be or not to be
Nord Stream built
Stock market crash
Reached his hands up in the Arctic
Gas prices
The second wave of crisis
Boguchany HPP launched
Russia has joined the WTO

Hard-to-recover reserves: thermal gas-chemical exposure

Orenburgneft conducted successful pilot tests of a new technology for extracting hard-to-recover reserves based on thermal gas-chemical treatment (TGCT) of the formation.

The technology consists of thermal gas-chemical exposure by way of a solution of mixtures. The mixtures, when influenced by the activating substance, trigger a chemical reaction inside the formation.

Due to the intense temperature, the viscosity of the oil decreases and its mobility increases, making it possible to significantly increase oil recovery in the formation.

In addition, the violent release of a large amount of gases causes changes within the formation allowing the extraction process of immobile oil or slow-moving oil.

The technology has been tested on the layers of the Skvortsov and Bobrovsk deposits. The latter is multi-layered and multi-domed, and at the moment oil reserves are dispersed in small deposits that are confined to different domes.

Therefore, the introduction of the TGCT technology has great prospects. As a result of works carried out, more than 2 thousand tons of oil was additionally produced from two pilot wells. The duration of the effect after treatment of the bottomhole zone lasts more than 8 months.

Record setting with Fishbone

Taas-Yuryakh Neftegazodobycha has set a new drilling rate record while conducting extraction procedures in a multilateral well.

The total length of the horizontal hole of the oil well in the formation was 6,052 m, which exceeds the previous achievement of Taas-Yuryakh Neftegazodobycha by 800 m, recorded 5 months ago (December 2018) at the Srednebotuobinskoye field.

This is the longest horizontal section of a multilateral well on earth.

The length of the main hole of the record oil well is 1407 m and there are 7 lateral holes – from 334 to 1006 m.

During the planning process, specialists of Taas-Yuryakh Neftegazodobycha modeled the operation of the oil well on a geological and hydrodynamic simulator and carried out work on the selection of tools and downhole equipment.

The initial production rate was more than 200 tons of oil per day.

Green 3D-seismic technology for Bazhenov

During the past field season, Gazpromneft-Khantos conducted a 3D survey of a territory with an area more than 1,200 km^2 in the Khanty-Mansiysk Autonomous Okrug. The surveys were carried out using the "green seismic" technology, based on the RT System2 wireless data acquisition system. This method allows to enhance the production cycle by accelerating the installation of seismic receivers in a complex landscape.

Owing to the use of light snowmobiles instead of large-sized equipment, it was possible to reduce the width of the glades for the installation of sensors two-fold, up to 1–2 m, thereby preserving significant forest areas.

A comprehensive analysis of the seismic survey results will pave the way for the creation of an accurate geological model of the objects under study and the confirmation of forecasts made earlier.

This is especially true for the Palyanovskaya area of the Krasnoleninskoye field – one of nine subsoil plots where the Bazhenov Technology Centre is located developing profitable technologies for oil production of the Bazhenov formation.

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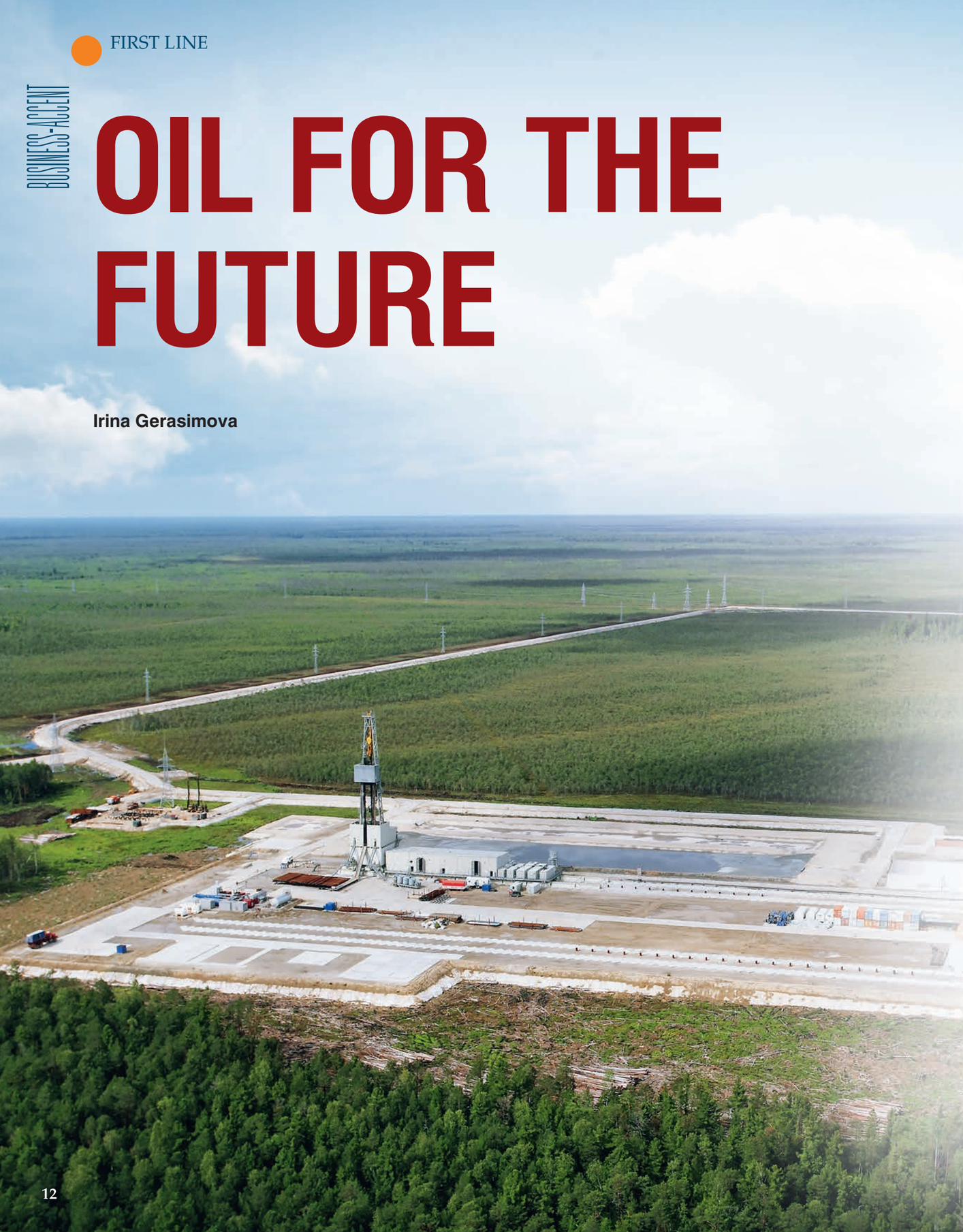
BUSINESS-ACCENT

OIL FOR THE FUTURE

Irina Gerasimova



THE DEVELOPMENT OF THE BAZHENOV FORMATION IS ONE OF THE STRATEGIC DIRECTIONS DESIGNED TO SAVE THE RUSSIAN OIL INDUSTRY FROM A SHARP DECLINE IN PRODUCTION IN THE NOT TOO DISTANT FUTURE. THE PROSPECTS HERE ARE SUBSTANTIAL – IT IS ESTIMATED THAT BILLIONS OF TONS OF HYDROCARBONS COULD BE EXTRACTED. BUT THE NEXT STAGE – ON HOW TO TACKLE THE EXTRACTION PROCESS – IS NOT YET CLEAR

Second breath of life for Siberian oil companies

The Bazhenov Formation is a horizon containing oil source rock and highly productive lenticles in some areas. In addition to liquefied petroleum, rocks include solid organic matter – kerogen (immature oil), which is the main potential of the deposit. The Bazhenov Formation is located in Western Siberia on an area of 1.2 million square kilometers, in the old areas of oil production, but at a depth of 2–3 km, that is, below traditional reservoirs.

The formation was discovered back in 1959. Now more than 70 deposits are confined to Bazhenov, and most of them are located in the Khanty-Mansiysk Autonomous Okrug – Ugra.

Opinions on the Bazhenov Formation reserves vary greatly. According to forecasts, the volume of geological reserves reaches 18–60 billion tons, indicated on the website of the Ministry of Energy of the Russian Federation. In the future, it is possible to extract from 700 million to 5 billion tons, as cited earlier by the Minister of Energy Alexander Novak. However, there are more optimistic assessments.

The development of the formation can give "a second breath of life" to West Siberian oil fields that are gradually becoming depleted in terms of traditional reserves. Moreover, the Bazhenov Formation contains oil that is light, low-sulphur, and it exceeds the quality of Brent. Russia believes that it is even possible to create a commercial brand of such oil.

However, it is extremely difficult to extract the precious crude oil of the Bazhenov deposits. The oil-bearing rock is extremely dense with a low level of permeability. These deposits occur at considerable depths and the thickness is often measured to be only 20–30 m. Furthermore, the formation is extremely non-uniform in composition, and the distribution of oil in it is uneven. The study of deposits is also difficult due to the fragility of source rocks making it difficult to select and examine the core.

For these reasons, the development of the Bazhenov Formation was considered to be unpromising for several decades.

FACTS

In 1959

Gurari F.G. identified a group of oil source rocks in Western Siberia with an area of 1 million km², called the Bazhenov Formation

Projects

The interest of oil industry workers to Bazhenov started in the early 2000s. Surgutneftegaz was the first company to start production in 2005. To date, the company has drilled over 600 oil wells, mainly at the Ay-Pimskoye field in the Khanty-Mansiysk Autonomous Okrug. Surgutneftegaz receives 500-600 thousand tons of oil per year from Bazhenov deposits placing the company in first place in terms of the volume – up to 800 thousand tons per year.

RITEK (LUKOIL group) also began operations in the early 2000s. The company has formed three pilot sites at the Sredne-Nazymskoye field in the Khanty-Mansiysk Autonomous Okrug where it develops extraction technologies. The company's current production exceeds 100 thousand tons per year. LUKOIL also has the Galyanovsky section and several other sites of the Bazhenov Formation.

Since 2009, Rosneft has been developing Bazhenov deposits in the Salym field. Exploration works are conducted on other West Siberian assets of the company, including the Priobskoye field.

RussNeft also launched its pilot project for the exploration of the Bazhenov Formation. In 2017 the company began drilling at the Sredne-Shapshinskoye field in Khanty-Mansiysk Autonomous Okrug.

Gazprom Neft embarked on the development of Bazhenov around 2010 as part of a joint venture with Shell and Salym Petroleum Development (SPD). Gradually, the company launched projects in the Palyanovskaya area of

the Krasnoleninskoye field, the southern part of the Priobskoye field in the Khanty-Mansiysk Autonomous Okrug, the Vyngayakhinskoye field in the Yamalo-Nenets Autonomous Okrug and several others.

After the imposing of sanctions in 2014, cooperation with Shell on Bazhenov had to be curtailed. Other projects also suffered: Rosneft's project with Exxon Mobil and LUKOIL's project with Total.

As of now, Gazprom Neft, with the support of the authorities of the Khanty-Mansiysk Autonomous Okrug and federal specialized ministries, has established the Bazhen Technology Centre (registered in July 2018). The organization became the operator of the technological test site as part of the project to develop the Bazhenov Formation. The Palyanovskaya area of the Krasnoleninskoye field is used by the centre as the technological platform. The Technology Centre received the status of a specialized national project and now includes more than 20 participating partners — research institutes and companies. It is expected that the project will soon be granted federal status.

In search of the right way forward

Today, production from Bazhenov is still marginal or even unprofitable, and oil industry workers continue to search for the right way forward. The main problem is that high-performance technologies, allowing to obtain Bazhenov oil in large volumes, are not available to anyone in the world.

Experts point out that in order to develop the Bazhenov Formation it is impossible to simply borrow the methods used for shale production from the United States. And this is not due to sanctions, but owing to the difference in geological properties of the deposits.

Russian companies have to go their own way. And work is now being conducted mainly in two directions.

The first direction is the adaptation of technologies used in the American shale fields, that is, a combination of horizontal drilling and multi-stage hydraulic fracturing (MHF). Rosneft and Gazprom Neft are particularly active in this area. Rosneft first applied this method to the Bazhenov deposits on the Priobskoye field in 2011. Seven hydraulic fracturing procedures were successfully carried out on a horizontal wellbore and, as result, a high initial production rate was received (almost 250 tons per day).

In 2016, Gazprom Neft announced that it was the first oil company in Russia to implement the entire cycle of technological solutions used in the world

FACTS

More than **70**

deposits are located in the Bazhenov Formation

Up to **5** billion tons

of prospective extractable oil reserves

to develop shale oil. Alexander Dyukov, the head of Gazprom Neft was quoted as saying: "...despite all the restrictions due to sanctions, we passed on a set of technologies that allowed us to produce oil from the Bazhenov Formation exclusively through the use of Russian technologies and Russian equipment, and all work was carried out by Russian contractors". (TASS news agency).

The second direction in the sphere of technologies for the development of Bazhenov involves methods of enhanced oil recovery (EOR), such as thermochemical and thermal gas methods. Here Russia has a lot of its own developments. For example, Surgutneftegaz has been researching thermal methods of production since the beginning of the 2000s, in particular, the technology of wet in-situ combustion.

Since 2009, RITEK has been testing the technology of thermal gas impact on the deposits of the Bazhenov Formation of the Sredne-Nazymskoye field, which is often noted as one of the most promising in terms of recovery. The technology involves the injection of air and water under high pressure into the reservoir. As a result of oxidation, carbon dioxide and NGL are released, which together with nitrogen force the oil into production wells. At the same time, under the influence of thermal effect and pressure, additional fracturing is created in the deposit. Kerogen is converted into light oil and hydrocarbon gases. The use of thermal gas impact in combination with maintaining reservoir pressure allows to increase the oil recovery factor (KIN) up to 20–30%, according to data by RITEK.

Today, companies combine EOR methods with drilling horizontal and inclined wells, as well as multi-stage hydraulic fracturing.

Domestic equipment is also being produced for the development of the Bazhenov Formation. For instance, the Bazhenov Technology Centre created a set of equipment and

technologies for the thermochemical treatment of oil wells using supercritical water that helps to significantly increase oil recovery. "This method has no analogues in the world", said Kirill Strizhnev, Director General of the Bazhenov Technology Centre, in his recent interview to the Prime agency. Moreover, oil companies are developing specialized software packages.

Anticipating a breakthrough

Extraction of oil from Bazhenov can become profitable in the upcoming years. Now the cost of a barrel of such raw materials is at the level of $60, but by 2021 it may drop to $40 per barrel, according to Kirill Strizhnev. He added that an acceptable level of profitability would develop at a cost of $30–40 per barrel, provided that the barrel of oil on the market will be valued at $50.

The active growth of extraction is anticipated as well. Plans for the Bazhenov national project are aimed at increasing the rate to 10 million tons per year in 2025 and to 50 million tons by 2030.

However, to ensure that a breakthrough occurs, a wide range of problems should be solved first.

For a start, the geological structure of the Bazhenov formation has not been fully studied, which makes it difficult to find and develop technologies. Secondly, due to the imposed sanctions, there is not enough equipment – for example, for the drilling of intelligent wells as domestic technologies have not yet been created.

Experts also point to the need to combine the efforts of independent vertically integrated oil companies and research institutes in the quest for new technology. It is expected that this

FACTS

20-30 m

is the average thickness of deposits

platform will be the Bazhenov Technology Centre.

There is no question that in order to develop the Bazhenov deposits, active state support is needed. Today, deposits confined to Bazhenov are exempt from tax duty in accordance with MET. However, incentives are also required for the creation and application of innovative technologies.

Besides, the market is waiting for legislative changes. Now the introduction of the draft law on technological test sites is to be expected. The document proposes making the development of technologies for geological exploration, exploration and production of hard-to-recover reserves a separate type of subsoil use. The owners of such licenses will be exempted from one-time and regular payments for the use of subsoil.

In any case, there is little doubt in the market that the Bazhenov Formation and other areas with hard-to-recover reserves must be developed. There is no time to waste. Otherwise, last year's predictions of the Saudi prince about Russia's complete withdrawal from the oil market may well come true.

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RESERVOIR PRESSURE MAINTENANCE

Experience in the development and implementation of water treatment systems under field conditions

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Head of the Department of Machinery and Equipment for Oil and Gas Fields Gubkin Russian State University of Oil and Gas, Professor, Doctor of Technical Sciences

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THE EFFECTIVENESS OF THE APPLICATION OF RESERVOIR PRESSURE MAINTENANCE SYSTEMS DIRECTLY DEPENDS ON THE PRESENCE OF SOLID SUSPENDED PARTICLES IN THE PROCESS AND FORMATION FLUID. TO ENSURE THE REQUIRED HIGH QUALITY OF WATER, A MODULAR WATER TREATMENT SYSTEM (WTS) WAS DEVELOPED AND IMPLEMENTED. THE SMALL SIZE AND MODULARITY OF THE WTS ALLOWS TO ACHIEVE THE REQUIRED PERFORMANCE CONDITIONS AND FACILITATES INSTALLATION AND MAINTENANCE AT VARIOUS FACILITIES OF THE RESERVOIR PRESSURE MAINTENANCE SYSTEMS

UDC 684

KEYWORDS: *reservoir pressure maintenance system, water quality, suspended particulate matters, mechanical impurities, Water Treatment System, WTS, filter unit.*

The effectiveness of the application of reservoir pressure maintenance systems directly depends on the presence of solid suspended particles in the process and formation fluid. The presence of suspended particulate matters (SPMs) reduces the effectiveness of operations for reservoir pressure maintenance (RPM) and field oil treatment (FOT) due to:

- abrasive wear of surface and well equipment;
- reducing the injectivity of the bottom-hole formation area of injection wells;
- increasing consumption of reagents for the separation of well production during FOT.

That is why the number and size of SPMs in water is strictly regulated by the enterprise standards (ESs) and industry standards (ISs).

The industry standard IS 39-225-88 (Table 1) strictly regulates the permissible size and content of mechanical impurities and oil, depending on the openness of the reservoir.

This standard does not take into account the “contaminant capacity”

TABLE 1. Requirements for water quality of reservoir pressure maintenance (RPM) systems

Indicator	Openness of porous reservoir rock, μm²	
	up to 0.1	more than 0.1
Limitation of mechanical impurities in water, mg/l	3	5
Limitation of oil in water, mg/l	5	10
Limitation of particle size of mechanical impurities (not less than 90%), μm	1	5

of the reservoir that depends on the formation thickness, as well as the priority of the size of suspended particles in relation to their quantity. Some enterprises develop specifying ESs taking into account the specific features of reservoirs.

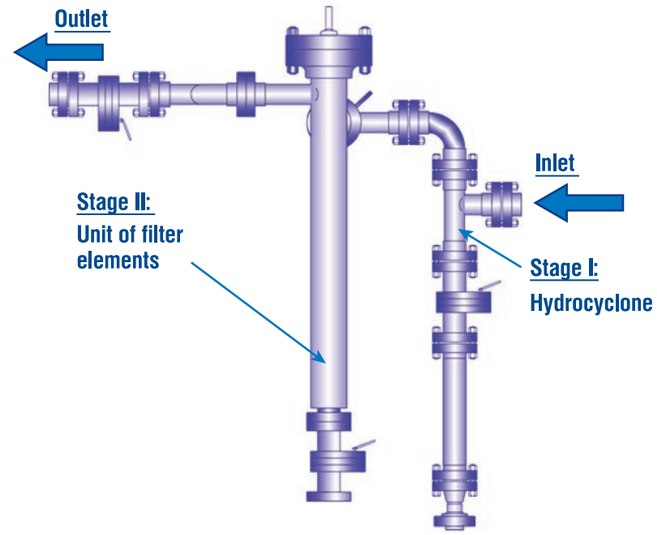
To ensure the required high quality of water, a modular water treatment system (WTS) was developed. Depending on the operation conditions, it may include up to two treatment stages (Fig. 1). The first stage is a cyclone separator of mechanical impurities of required carrying capacity, the second stage is a filtering part with a unit of filter elements [1].

Depending on the requirements for the WTS, first of all, the purpose and the fineness of treatment various designs are proposed for the use.

Fig. 2 (a) shows a single-stage WTS, which is used to treat the breakdown fluid supplied to the jet pump unit (JPU) installed in the lateral hole of small diameter (SDLH). The first stage is included in the JPU delivery and eliminates the likelihood of clogging and abrasive wear of the pump nozzle, which ensures that the pump remains operational.

The diagram in Fig. 2 (b), the most common option, is a two-stage WTA

FIG. 1. Two-stage water treatment system



unit for water treatment directly at the injection wellhead. This placement option removes not only mechanical impurities that may be present in water, but also corrosion products of pipelines connecting the elements of the RPM system. This ensures the quality of water that enters the well. These options are designed for individual water treatment at the wellhead.

Today, the carrying capacity of the WTS (up to 800 m³/day) allows to install it at the inlet or outlet of the SPS or the pipe manifold for servicing several wells (Fig. 3). In the case of installing as shown in Fig. 3 (b), the unit will protect the pump unit from abrasive wear and due to the low operating pressure will be less metal-consuming and lower in its price.

One of the types of installation of the WTS unit at the inlet to the pumping unit is the use of the WTS at the wellhead with the boring shore unit (Fig. 4). The use of WTS protects the submersible pump

FIG. 2. Diagrams of WTS unit application

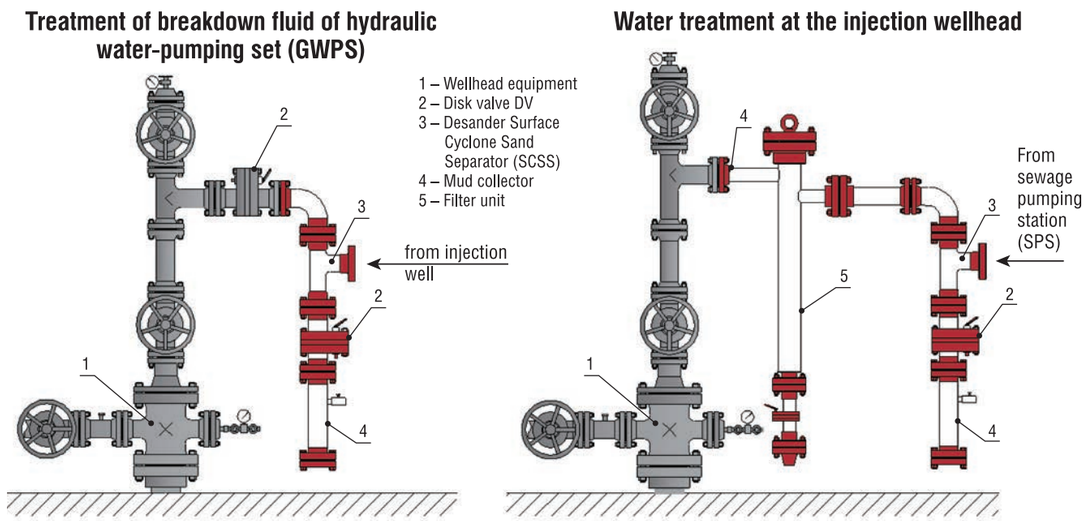


FIG. 3. WTS unit diagram at the SPS outlet (a) and inlet (b)

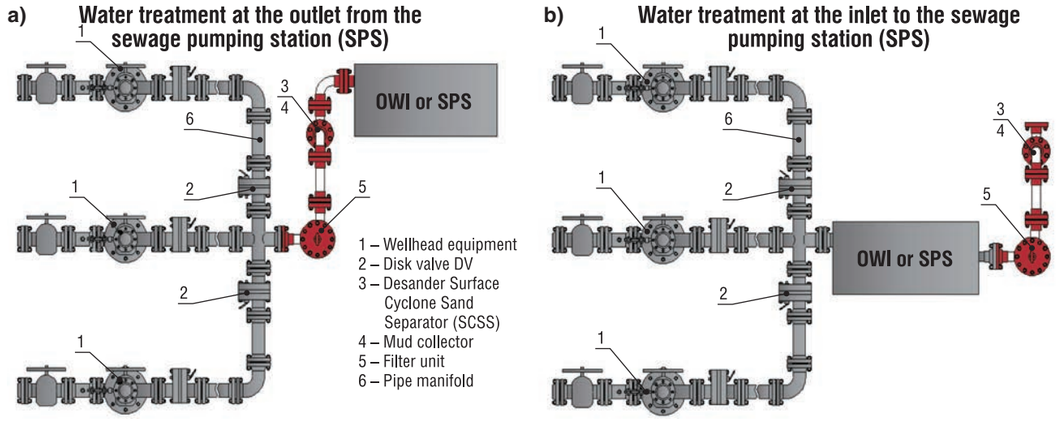


FIG. 4. WTS diagram at the boring shore unit head

against abrasive wear and clogging, the dismantling of which requires the involvement of the well production maintenance (WPM) team.

Fig. 5 shows the option of installation of the WTS at the preliminary water discharge unit (PWDU) between two separation tanks. The advantage of this option is no need to travel to the wellhead to control the operation and cleaning of the WTS. Maintenance personnel can timely clean the WTS and thereby prolong the effective use of filter element units.

This installation diagram was implemented at the field of LUKOIL-PERM LLC. As the tests showed, the suspended particulate matters content decreased from 57.3 to 19.5 mg/l, the residual oil content from 107.4 to 59 mg/l, and the average particle size from 4 to 2.5 μm. The maximum particle size decreased from 29.5 to 10.4 μm, while more than 40% of the particles in treated water are not more than 1.39 μm in size [1,3].

Table 2 shows the technical characteristics of WTS units commercially available to date. To test the WTS unit in order to determine the separation efficiency, pressure difference under various operating conditions (fluid supply, size and content of SPMs), clogging time and regenerating ability, as well as to pressure welded joints, a test bench was developed and assembled at the manufacturer's site [3, 4].

Following the bench tests of the WTS-80x21-800 water treatment unit, the separation ratio of the first stage was 98.8%. The remaining mechanical impurities were

FIG. 5. WTS diagram at the preliminary water discharge unit

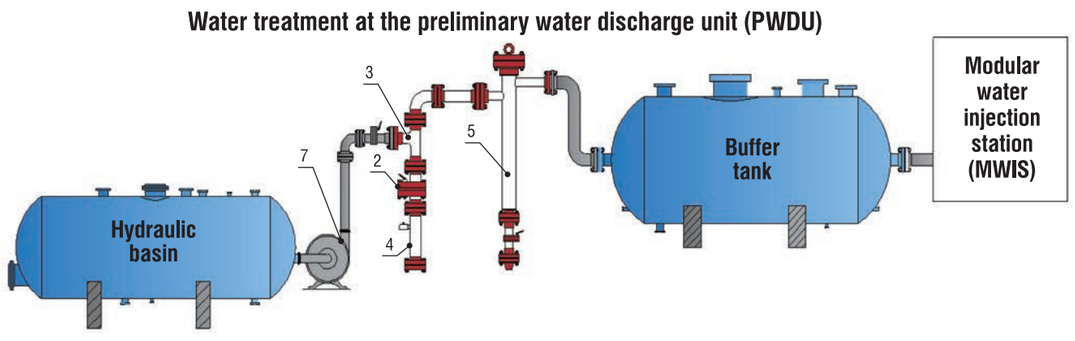


TABLE 2. Technical characteristics of WTS units

No.	Parameter	Designation	Measuring Unit	Value		
				WTS-65x21-250	WTS-80x21-400	WTS-80x21-800
1	Flow rate	Q_{max}	m³/day	250	400	800
2	Operating pressure	P_{oper}	MPa	21	21	21
3	Diameter of SCSS separator	D_{SCSS}	mm	89	114	114
6	Maximum height	H_{max}	mm	2 000	2 400	2 400
9	Width	B	mm	2 210	2 240	2 240
10	Length	L	mm	2 000	2 360	2 360
13	Drain connection type			upon request of the Customer (blind flange or make-and-break coupling)		

successfully removed at the second stage. The pressure difference at a carrying capacity of 600 m³/day was no more than 7 atm (Fig. 7). The WTS unit successfully passed pressure tests with a pressure of 25 MPa.

To date, the carrying capacity of the WTS unit is 800 m³/day. More than 60 WTS units have been produced and operated in many oil and gas companies in Russia, as well as in the fields of Kazakhstan and Romania.

The pilot tests were carried out successfully and of WTS units were introduced in the companies: LUKOIL-PERM LLC, Messoyahaneftegaz JSC and T&IC RITEK Beloyarskneft [2, 4].

In LUKOIL – Western Siberia JSC, pilot tests were recognized as unsuccessful due to non-compliance with the pressure difference condition. ●

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FIG. 6. Test bench diagram

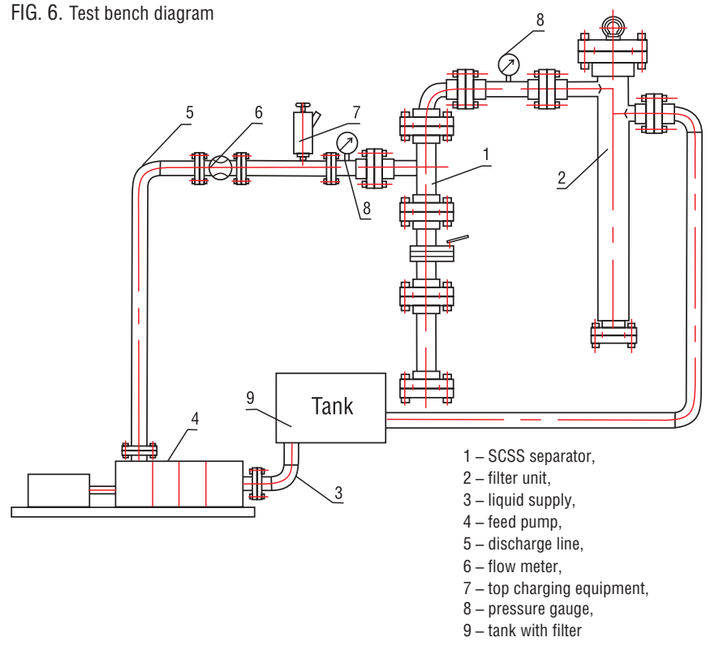
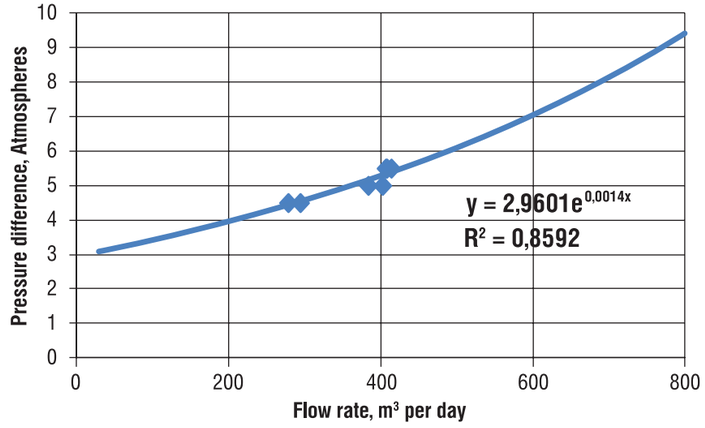


FIG. 7. Pressure difference at the WTS and fluid supply dependence graph



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UDC 622

NOVATEK-TARKOSALENEFTEGAZ LLC AND YAMAL BRANCH OF JSC SSC – SECOND FIVE-YEAR COOPERATION PLAN CONTINUES

Alexey Rybalkin,
Deputy Director General for Drilling and Well Workover
NOVATEK-TARKOSALENEFTEGAZ LLC

THIS YEAR, NOVATEK-TARKOSALENEFTEGAZ LLC, A SUBSIDIARY OF PJSC NOVATEK, THE LARGEST INDEPENDENT PRODUCER OF NATURAL GAS IN RUSSIA AND ONE OF THE LEADERS IN THE PRODUCTION, PROCESSING AND MARKETING OF HYDROCARBONS WILL CELEBRATE ITS 25TH ANNIVERSARY. DURING 25 YEARS, THE MAIN-EMPLOYMENT ENTERPRISE OF THE TOWN OF TARKO-SALE HAS MADE A HUGE CONTRIBUTION TO THE DEVELOPMENT OF THE FUEL AND ENERGY COMPLEX BOTH IN THE YANAO AND IN RUSSIA AS A WHOLE. TODAY NOVATEK-TARKOSALENEFTEGAZ IS A GOOD EXAMPLE OF COORDINATED WORK BY MANAGEMENT AND A TEAM OF LIKE-MINDED PROFESSIONALS AIMED AT ATTAINING NEW LABOUR ACHIEVEMENTS. ALEXEY RYBALKIN, DEPUTY DIRECTOR GENERAL FOR DRILLING AND WELL WORKOVER OF NOVATEK-TARKOSALENEFTEGAZ LLC, SPOKE ABOUT THE ALLURE OF THE OIL AND GAS INDUSTRY TO PROFESSIONALS, PRODUCTION ACHIEVEMENTS OF THE COMPANY AND UPCOMING PLANS

KEYWORDS: *oil production, fuel and energy complex, well workover, Siberian Service company, NOVATEK-TARKOSALENEFTEGAZ, exploration and production drilling, oil service.*

– Alexey Alexandrovich, during your professional experience, to what extent has the technology of drilling oil and gas wells changed? Is great allure still present in the profession of the modern driller?

– I have worked in this sphere for fifteen years and the oil and gas industry has definitely made a huge step forward. If earlier, for example, industry workers began to drill using a drive drill pipe, now the drilling rigs are equipped with above-ground drive systems and there are technologies using a rotary-controlled system. Wells are becoming more complex with large deviations from the vertical position. In old oil rigs, it was possible to drill only till certain depths. The norm was to construct inclined wells, but now almost all wells have horizontal tracks. At present, NOVATEK-TARKOSALENEFTEGAZ LLC, primarily drills wells with horizontal sections with lengths from 1200-1500 meters located in deposits with large formation pressure.

Moreover, social and living conditions near oil wells have improved substantially. Quite often I visit the production sites to communicate with employees, so I can say that the staff is happy with the work conditions and essential services.

Is there a place for great allure? I think in our modern world this concept has faded away. But one thing is for sure – the importance of the team. A drilling crew is one strong unit with each professional playing an integral part of the large system at complex and dangerous production facilities. The drillers take on huge responsibilities and their profession is associated with heavy physical labour and requires much endurance. Not everyone is able to cope with the pressure – only the loyal, courageous and brave ones who have connected their lives with the oil and gas industry are dedicated to this job.

FACTS

1200-1500 m

Predominant length of horizontal sections of wells drilled by NOVATEK-TARKOSALENEFTEGAZ LLC

– I suppose this holds true for the team of NOVATEK-TARKOSALENEFTEGAZ LLC and the personnel of your company's contracting organizations. What can you say about the Yamal branch of SSC as a contractor?

– To begin with, the Yamal branch of the Siberian Service Company and NOVATEK-TARKOSALENEFTEGAZ LLC have been cooperating for more than seven years. If you delve into the history, we first worked with the Strezhevsky division, which, in connection with the relocation into the Yamal-Nenets Autonomous District, was renamed the Yamal branch. Today, SSC is among the top 5 Russian drilling companies, and its northern division occupies one of the leading positions among our contractors. There are, of course, both advantages and disadvantages. But it is worth noting that a lot has changed within the past two and a half years: the entire fleet of drilling rigs has been unified, a professional team has been formed, which is successfully fulfilling all assigned tasks both in terms of the number of wells built and by meters of penetration. All current issues are resolved in the usual course of business, promptly and without excessive involvement of the management staff. In total, the Yamal Branch has built 28 production wells at

the East-Tarkosalinskoye and East-Tazovskoye fields. In less than four months of 2019, four production wells were drilled, and in regard to the network schedule we were 25 days ahead of schedule. All wells were drilled with acceleration, the commercial speed was increased from 2884 to 4130–4360 meters per machine-month. In the first quarter of 2019, the overall drilling rate at the East-Tarkosalinskoye field was 4,200 meters with a planned one of 3,700 meters.

– You mentioned that the Yamal branch occupies a leading position among the contracting organizations of NOVATEK-TARKOSALENEFTEGAZ LLC. What criteria are taken into account during assessment?

– First of all, we estimate the time of well construction, technical and technological equipment, we take into account the amount of minimum non-productive time, the absence of accidents and the organization of work in general.

We also pay close attention to the issues of improving the reliability of equipment operation at hazardous production facilities, preserving the integrity of the natural environment, improving social and living conditions of labour, as well as the safety and health of workers. For this purpose, audits are regularly conducted on-site. In respect to the Yamal branch, it can be said that the contracting organization seeks to follow the regulatory requirements and eliminates all identified concerns in time. As part of compliance with environmental requirements while drilling wells, the technology of pitless drilling is used.

For us, as customers, it is not so much the quantity that matters, but the quality and safety on all levels. We demand the same from our contractors.

– What else distinguishes the Yamal branch of SSC from other service companies?

– The ability and skill within the shortest possible time and without any deviations to implement works on the mobilization and installation of drilling rigs. The latest relocation of two drilling units BU 5000/320 EK-BMC was from the 23rd and 42nd well cluster of the East-Tarkosalinskoye field to the cluster platforms No.2 and No.3 of the East-Tazovskoye OGCF. And this is quite a long distance. However, everything was organized properly.

In my opinion, in the drilling sphere there are generally two components of success. The first is the team, starting from the drilling crews and ending with the management team. The second is the equipment and technical component that has to meet all modern requirements for oil well construction. The management staff of SSC understands that the combination of these elements is the key to success and the way to implement the assigned tasks, therefore it strives to be guided by this principle.

FACTS

More than **25**

days ahead of schedule in the construction network plan of production oil wells in less than four months

4200 m

commercial drilling rate at the East-Tarkosalinskoye field in the 1st quarter of 2019

– What are your plans for the near future?

– To complete the construction of facilities at the North-Russkoye field in the Tazovsky district of the YaNAO. According to plans, the first gas should flow from this site this year. Two stages have been outlined. The first one is the Senomanskoya technological line, the launch of which is scheduled for 2019. The second is the Valanzhinskaya technological line, which is scheduled for commissioning in the first half of 2020.

Currently, the Yamal branch has begun drilling wells at cluster platforms No.1 and No.2 of the East Tazovskoye field. These wells with a length of up to 6000 meters will be much more difficult to complete. As far as I know prior to this, SSC hadn't conducted such operations. Nonetheless, I am confident that together we will cope with the task ahead of us.

Last year, on the same field, work on drilling four wells with a length of more than 5000 meters was done quite properly and without delay at well cluster No.3. Based on results of their testing, the expected production rate was confirmed.

– In conclusion, could you express your wishes to colleagues, partner companies and contracting organizations.

– I hope for stability, prosperity and accident-free drilling operations, in regard to employees and their families – I wish them well-being, health and success!

PRODUCT FOR EFFECTIVE FILTRATION

REDUCING FINANCIAL LOSSES CAUSED BY THE DOWNTIME OF OIL WELLS AND THE REPLACEMENT OR REPAIR OF OIL-PRODUCING EQUIPMENT IS IMPOSSIBLE WITHOUT EFFECTIVE FILTRATION OF THE PRODUCT BEING EXTRACTED. CRUDE OIL AND NATURAL GAS ARE FOUND IN THE PORES, CRACKS AND VOIDS OF ROCKS. THE BEST RESERVOIRS WITH HIGH PERMEABILITY FOR OIL AND GAS ARE SANDS, SANDSTONES, LIMESTONES AND THEIR CONGLOMERATES. WHEN PUMPING OIL AS A RESULT OF SUFFUSION, THE SMALLEST FRACTIONS OF SAND AND ROCK PARTICLES ARE CARRIED OUT, WHICH LEADS TO RAPID WEAR AND FAILURE OF OIL-PRODUCING EQUIPMENT

KEYWORDS: *equipment for oil production, simple wells, well completion technology, lifting operations, well filters.*

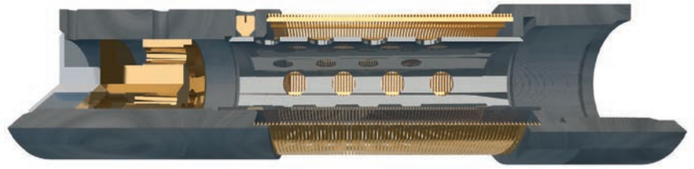
Sergei Belousov,
Chief Specialist
TMC Group LLC

Advanced well completion technologies involve the installation of filters in the interval of the productive horizon to prevent the removal of mechanical particles and the destruction of the bottomhole zone in weakly cemented reservoirs. Filters go down the casing string.

Standard requirements for downhole filters are: maximum flow area of the filter element and minimum clogging of its flow area during operation. When choosing a filter, the granulometric composition of the rock is taken into account, that is, the quantitative content of different grains in the rock in percentage for each fraction, the porosity, the extracted product viscosity in formation conditions, formation permeability, well production rate, formation pressure, temperature, size of the casing string, chemical and physical characteristics of the extracted product, etc.

In recent decades, traditional mesh filters have been replaced by filters, which have several advantages compared to the mesh ones. They provide an increase in the filtration surface by optimizing the geometrical dimensions of the triangular V-shaped section, due to which the well production rate increases, the filter load intensity decreases and its run-life increases. They contain several supporting elements, due to which the strength characteristics increase both in the axial and in the radial direction. Advantages also include corrosion resistance

and heat resistance of the material from which the elements of the slotted filter are made. There are no fractures or edges in the places of contact welding, which eliminates the likelihood of corrosion during long-term operation. In addition, slotted downhole filters easily restore working capacity after washing, acid treatment of the external filtering surface due to its openness and polishing.



When installing the filter in the interval of the productive formation of the well, it is in direct contact with the reservoir, and the filtered medium passes through the slots of the filter element, and then through the holes in the perforated pipe into the internal cavity of the pipe, from where it is pumped to the wellhead.

TMC Group LLC successfully produces well tube filters with a diameter of 73 mm to 273 mm, as well as all the necessary equipment for the installation of filters in the well.

The filter housing is made in the form of a perforated pipe on which the filter element is mounted, with a slit size of the filter element from 0.15 mm to 1.25 mm. The grain size of oil-bearing rocks, as a rule, ranges from 0.2 to 1.5 mm.

Filters manufactured by TMC Group LLC have passed industrial tests in the systems of PJSC Tatneft, PJSC Lukoil and PJSC Rosneft and have proved to be excellent earning high marks from field personnel.

TMC Group LLC successfully produces well tube filters with a diameter of 73 mm to 273 mm, as well as all the necessary equipment for the installation of filters in the well

Until recently, the application of slotted filters was relatively scarce, however, currently the production strings of the newly drilled wells are increasingly equipped with slotted filters. With the accumulation of operating experience of well tube slotted filters, field workers are convinced of their advantages. As the main oil and gas departments of the chief oil company of the republic started using slotted filters, they became popular with smaller oil companies of Tatarstan which are now actively interested in the slotted filters SLIDE, SPONGE and SILVERLINE, manufactured by TMC Group LLC.

Filters manufactured by TMC Group LLC have passed industrial tests in the systems of PJSC Tatneft, PJSC Lukoil and PJSC Rosneft

Currently, the need for well tube slotted filters in our country is about 40 thousand units per year and several enterprises are engaged in their production. Filters are used not only in the oil industry, but also in other sectors of the economy. Management Company TMC Group LLC has its specific direction in this area: the company specializes in the production of well tube slotted filters for casing strings of oil wells (SILVERLINE) and well tube slotted filters for sucker rod pumps (SLIDE and SPONGE). The well tube slotted filter SLIDE is a self-cleaning filter, in the lower part of the filter, in the bore of the filter housing there is a spool installed, which comes into operation in case of complete clogging of the filter element. Due to the pressure drop inside the filter housing and in the cap under the spool. The reciprocating movement of the spool caused by the movement of the produced fluid provides self-cleaning for the filter.

In the coming years, taking into account customer orders, there are new designs for joint operation with plug-in beam pumping units ⌀ 32 mm.

In the future, there are plans to release filters with an internal filter element located inside the filter housing. Filters of this design are reusable which means that several cycles of lifting operations can be carried out in the well.

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BLACK SHALES OF THE BAZHENOV FORMATION

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THE RESULTS OF A COMPREHENSIVE MINERALOGICAL AND GEOCHEMICAL STUDY OF THE BAZHENOV FORMATION ROCKS ARE PROVIDED. ACCORDING TO THE DATA OBTAINED, THE FORMATION IS HETEROGENEOUS IN ITS COMPOSITION. CARBONATE AND ALUMINUM-SILICEOUS (WITH A VARIABLE AMOUNT OF CLAY MINERALS, CHLORITE AND ILLITE) LITHOTYPES WERE IDENTIFIED. IT IS SHOWN THAT CARBONATE-FREE ROCKS SATURATED WITH ORGANIC MATTER ARE ENRICHED WITH NI, ZN, MO, BA, GD, DY, AU, U AND SOME OTHER ELEMENTS. CLUSTER ANALYSIS REVEALED THREE GROUPS OF CHEMICAL ELEMENTS: "PHOSPHATOPHILE", "CHALCOPHILE" AND "CLASTOPHILE". USING THE METHOD OF SCANNING ELECTRON MICROSCOPY WE REVEALED MINERAL PHASES OF SOME CHEMICAL ELEMENTS: BARITE, PYRITE, GOLD, ETC. THERE ARE THREE OCCURRENCE FORMS OF URANIUM: DISSEMINATED – IN THE MATRIX OF ROCKS; SORBED –ON ORGANIC MATTER, AND URANIUM MINERALS (COFFINITE, PITCHBLENDE). THE PROBABLE REASONS OF BAZHENOV FORMATION ROCKS ENRICHMENT BY URANIUM ARE ESTABLISHED

UDC 552.574:550.4(571.1)

KEYWORDS: *Bazhenov formation, geochemistry, mineral composition, uranium.*

Black shales are quite widespread formations around the world. These rocks are characterized by elevated concentrations of P, U, Mo, V, As, Zn, Cu, Ni, Ag, Au, and some other chemical elements (Neruchev, 1982; Yudovich, Ketris, 1988; Vine, Tourletot, 1970, et al.). An example of such black shales in the territory of Western Siberia are rocks of the Bazhenov formation.

Deposits of the Bazhenov formation of the Upper Jurassic (the Volgian Stage) – Lower Cretaceous (the Berriasian Stage) are widespread throughout Western Siberia, covering an area of more than 1 million km^2 with an average thickness of 30 m (Braduchan et al., 1986, etc.).

A significant number of works (Gavshin, Zakharov, 1996; Zanin et al., 2011, 2016; Ploumann et al., 1977, etc.) is devoted to the geochemistry of microelements in rocks of the Bazhenov formation. However, new data obtained recently significantly expand and complement the works, including by our authors (Rikhvanov et al., 2015; Turyshev, 2016, etc.) devoted to the study of these formations.

FACTS

70 %

The rock mass is composed of terrigenous quartzo-feldspathic rocks with varying kaolinite and muscovite contents

Materials and methods

The material for the study was the samples of the Bazhenov formation taken from the drill-hole cores that open this formation within the Tomsk and Tyumen Regions, the Khanty-Mansiysk Autonomous Okrug. Collection samples for the study were provided by A.V. Ezhova (National Research Tomsk Polytechnic University), M.V. Shaldybin (TomskNIPIneft), V.V. Turyshev (Tyumen Industrial University), V.V. Khabarov (Tyumen Industrial University), E.A. Romanov (Tyumen).

The sampled material was subjected to a complex mineralogical and geochemical study using various analytical methods in the laboratories of National Research Tomsk Polytechnic University, TomskNIPIneft OJSC, Plasma Chemical Analytical Center LLC:

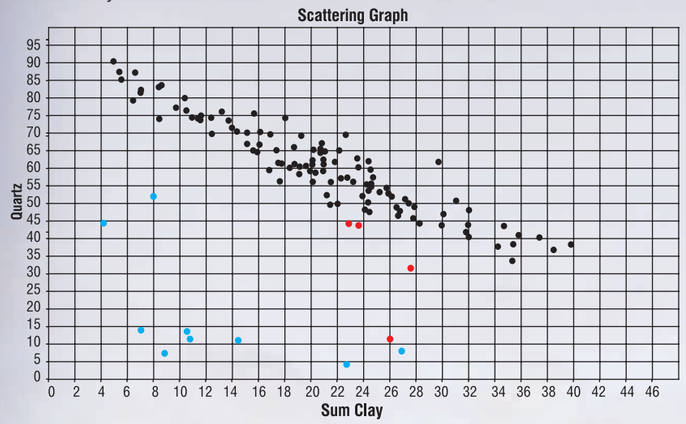
- petrographic studies (30 sections);
- X-ray diffractometry (132 samples);
- instrumental neutron activation analysis (28 chemical elements, 210 samples);
- inductively coupled plasma mass spectrometry (63 chemical elements, 10 samples);
- pyrolytic method (C_{org}, 134 samples);
- scanning electron microscopy;
- fission radiography (f-radiography).

Results and its discussion

Analysis of the results obtained based on petrographic, mineralogical and chemical studies showed a significant difference in the composition of the rocks of the Bazhenov formation, which confirms the opinion of some researchers that there are several lithotypes of rocks in the composition of the formation (Zanin et al., 2011, 2016, etc.).

Thus, the study of samples using the method of X-ray diffractometry made it possible to isolate

FIG. 1. Correlation of the content of quartz and clay minerals according to x-ray diffractometry



Note: hereinafter, black dots are clay rocks, blue dots are carbonate rocks; red dots – pyrite-containing (more than 20% pyrite) rocks

carbonate rocks (calcite, dolomite), predominantly, dolomite (the content of dolomite in samples is up to 85%) – up to 25% of all samples. Much less frequently (up to 5% of the total number of samples) calcite samples (the calcite content in samples is up to 67%) of the composition are found. Most of the rock mass (up to 70%) is composed of terrigenous quartzo-feldspathic rocks with varying contents of kaolinite, muscovite, sometimes replaced by illite. There is an inverse correlation between the content of quartz and the amount of clay minerals (Fig. 1). Throughout the entire rock mass (1 to 23.7%) pyrite of several typomorphic types is represented.

TABLE 1. Elemental composition of the rocks of the Bazhenov formation, g/t

Element	$x_{aver} \pm \sigma$	min...max	N	Element	$x_{aver} \pm \sigma$	min...max	N
Li	29.85 ± 6.89	12.98...50.98	10	Sn	1.61 ± 0.41	0.26...2.37	10
Be	<5		10	Sb	**4.86 ± 0.63**	**0.16...35.9**	210
Na*	0.58 ± 0.04	0.01...1.48	210	Te	<50		10
Mg*	1.11 ± 1.08	0.34...5.34	10	Cs	4.99 ± 0.42	0.1...16.1	210
Al*	4.48 ± 1.34	0.46...7.35	10	Ba	**1995 ± 538**	**120...45665**	210
Si*	23.1 ± 4.04	11.33...28	10	La	24.35 ± 2.7	0.05...255	210
P	1237 ± 792	211...3449	10	Ce	44.72 ± 3.3	2.86...235	210
K*	1.47 ± 0.42	0.11...2.33	10	Pr	5.6 ± 1.36	1.07...7.9	10
Ca*	2.55 ± 0.61	0.036...24.78	210	Nd	23.28 ± 1.71	0.5...100.22	210
Sc	12.51 ± 0.72	1...26.27	210	Sm	3.93 ± 0.41	0.037...23.06	210
Ti	3473 ± 927	469...5328	10	Eu	1.2 ± 0.1	0.038...8.1	210
V	**347 ± 121**	**102.4...677.0**	10	Gd	5.44 ± 1.41	1.36...8.62	10
Cr	74.7 ± 4.8	0.2...222.3	210	Tb	0.7 ± 0.07	0.003...5.507	210
Mn	580 ± 785	84.8...3576.2	10	Dy	4.55 ± 1.24	1.22...7.81	10
Fe*	3.93 ± 0.46	0.52...32.43	210	Ho	0.9 ± 0.28	0.31...1.69	10
Co	27.48 ± 2.67	0.05...151	210	Er	2.68 ± 0.75	0.91...4.59	10
Ni	**162 ± 68**	**52.55...280.07**	10	Tm	0.4 ± 0.11	0.15...0.67	10
Cu	**99 ± 34**	**27.76...163.67**	10	Yb	3.27 ± 0.27	0.29...21.85	210
Zn	**447 ± 49**	**1...2781.2**	210	Lu	0.45 ± 0.03	0.025...3	210
Ga	14.16 ± 3.7	2.23...22.09	10	Hf	2.63 ± 0.19	0.163...9.34	210
Ge	2 ± 0.61	0.9...4.2	10	Ta	0.35 ± 0.04	0.001...1.546	210
As	30.38 ± 3.19	0.05...149.91	210	W	1.24 ± 0.29	0.25...1.75	10
Br	<0.9		210	Re	**0.18 ± 0.11**	**0.01...0.48**	10
Rb	65.7 ± 5.24	1...177.7	210	Pt	<0.1		10
Sr	301 ± 51	10...3423	210	Au**	**15.07 ± 2.52**	**1...226**	210
Y	26.56 ± 9.48	10.84...54.98	10	Hg	0.17 ± 0.1	0.05...0.45	10
Zr	108.1 ± 23.5	22.37...144.11	10	Tl	2.78 ± 1.31	0.72...5.96	10
Nb	8.2 ± 2.15	1.28...13.18	10	Pb	15.04 ± 4.18	2.53...25.36	10
Mo	**151.6 ± 88.2**	**1.97...308.49**	10	Bi	0.25 ± 0.07	0.03...0.42	10
Ru	<0.5		10	Th	6.24 ± 0.47	0.05...22.3	210
Ag	<0.7		210	U	**38.29 ± 4.05**	**1.84...186.7**	210
Cd	**11.45 ± 7,07**	**0,26...28,12**	10	TOC*	**8,79 ± 0,7**	**0,78...19,65**	132
In	<0,5		10				

Note:
* – content is provided in %,
** – content is provided in mg/t,
x_{aver} – average,
σ – standard error,
min – minimum value in the sample collection,
max – maximum value in the sample collection,
N – number of samples tested, chemical elements exceeding the average for black shales were identified in bold (*Ketris, Yudovich, 2009*).

FIG. 2. Correlation of the content of C_{org} and clay minerals in the Bazhenov formation

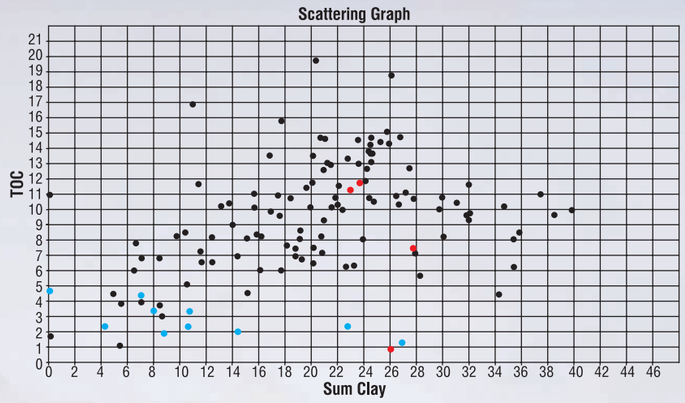
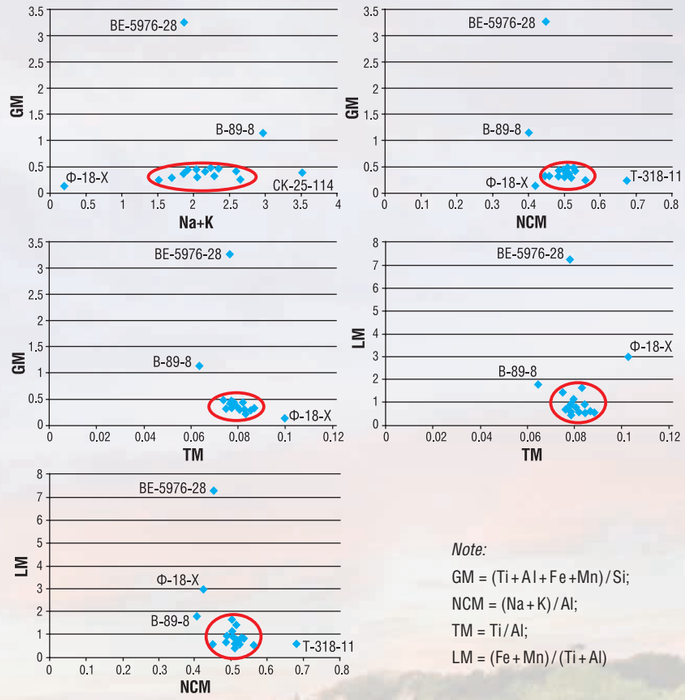


FIG. 3. Distribution of the rocks of the Bazhenov formation in the petrochemical modular diagrams (Yudovich, Ketris, 2000)



Note:
GM = (Ti + Al + Fe + Mn) / Si;
NCM = (Na + K) / Al;
TM = Ti / Al;
LM = (Fe + Mn) / (Ti + Al)

Organic matter saturates the entire rock mass and gives black color to it. Its amount ranges from 0.8 to 20%, with the average content of 8.8% (Table 1). Conspicuous is the presence of a significant amount of barite (up to 0.5%), sphalerite everywhere in all samples. It should be noted that high concentrations of barium in the rocks of the Bazhenov formation cannot be due to the use of barite-containing drilling fluids, as indicated by A. Y. Bychkov with co-authors (Bychkov et al., 2016).

A rather significant positive correlation is noted between Corg and pyrite, as well as between Corg and the amount of clay minerals (Fig. 2).

For dividing the rocks into lithological types, the geochemical approaches of Y.E. Yudovich were used (Yudovich, Ketris, 2000). Modular diagrams were constructed with certain assumptions, since the composition of the rocks is represented not in the form of oxide compounds (Fig. 3). The analysis of the modular diagrams confirmed the presence of one basic rock type and a number of others of subordinate significance. The main group included samples of the rocks enriched with organic carbon (more than 6%). Further study of the geochemical characteristics of the rocks of the Bazhenov formation was carried out taking into account the lithotypes.

The results of the study of the elemental composition of the rocks of the Bazhenov formation are presented in Table 1. Compared with the average values for black shales, these rocks are enriched with Ni, Zn, Mo, Ba, Gd, Dy, U and some other elements. The chemical composition of the rocks of the Bazhenov formation is similar to the Kuonam formation of theYakutian Cambrian (Fig. 4), which may indicate similar accumulation modes. Low concentrations of Br in both oil source rock masses are noteworthy.

Further geochemical schemes were made only for the alumina-siliceous group of the rocks. The carbonate rocks were not considered.

Cluster analysis was used to isolate the geochemical associations of elements. The isolation was carried out within the isolated uniform group of samples. Analysis of the results showed the presence of three clearly distinguished groups of

FIG. 4. Comparison diagram of the elemental composition of the rocks of the Bazhenov (J3-K1) and Kuonam ($Є_{1-2}$) formations (using samples of V.A. Kashirtsev)

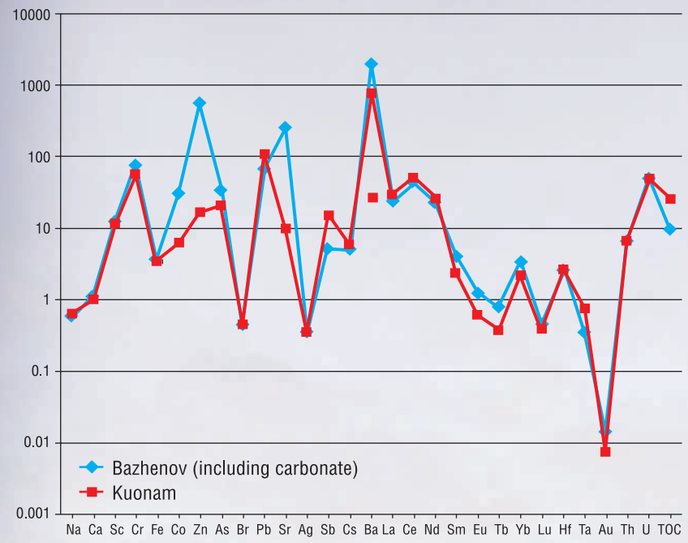
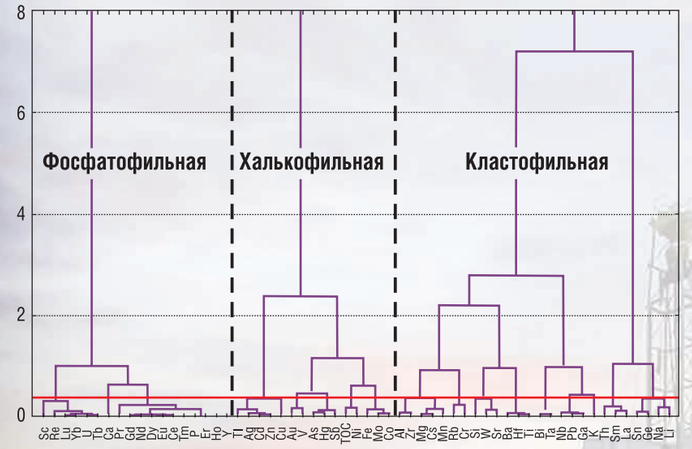


FIG. 5. Dendrogram of correlations between the contents of chemical elements in the rocks of the C_{org} rich Bazhenov formation (more than 6%)



chemical elements, which, in our opinion, reflect different conditions for the accumulation of the form of chemical elements (Fig. 5).

The following geochemical associations were distinguished:

1) “phosphatophilic”, which included P, Ca, Sc, a number of rare-earth elements, Re, U;

2) “chalcophilic”, which included mainly chalcophilic elements (Ag, Cd, Zn, Cu, Hg, Sb, Au, Mo, Tl), as well as some siderophilic elements and elements with variable valence (V, As, Ni, Fe , Co);

3) “clastophilic”, which included Ti, Cr, Zr, Hf, Ta, Nb, Th, W, Sn, Si, Al, Mg, K, Na, Li, Rb, Cs, Sr, Ba, Mn, Bi, Ge, Pb, Ga, Sm, La.

The high contents of a number of elements, as well as isolated geochemical associations are confirmed by a detailed electron microscopic analysis of the detected microphases. The mineral phases determined at this stage are shown in Table 2.

To date, we (Rikhvanov et al., 2015; Usoltsev, 2016) have identified our own microphases of 13 chemical elements, as well as groups of rare-earth elements. The form of Mo presence was not identified, although it is contained in the rocks of the Bazhenov formation in significant concentrations (average – 151 g/t).

The “phosphatophilic” group of elements is primarily represented by phosphate-calcium formations (relics of living organisms), in which microinclusions of U mineral phases spatially connected with Si (coffinite?) are found. These micromineral phases are in close association with the micromineral phases of P-Y (xenotime), which also contain rare-earth elements.

The “chalcophile” group is represented mainly by the mineral phases connected with S. These mineral phases are likely sulfides (Zn, Fe, As, Cu). In addition, these elements are quite often found in “non-sulfide” mineral phases containing Ag, as well as in the form of complex intermetallic compounds (Cu-Zn, Cu-Ni, Cu-Sn-Co, Au-Ag, Sn-Cu-Ni-Fe, V-Ti-Fe, etc.). However, the following elements were not included in the “chalcophilic” group: Pb which is likely represented by sulphide (galena); Sr and Ba which are found in mineral phases the composition of which corresponds sulfates of these elements (celestine? barite?); Sn which is found in the native form. Such an accumulation of chemical elements can be associated with a sharply reducing environment of the formation of carbonaceous rocks

FACTS

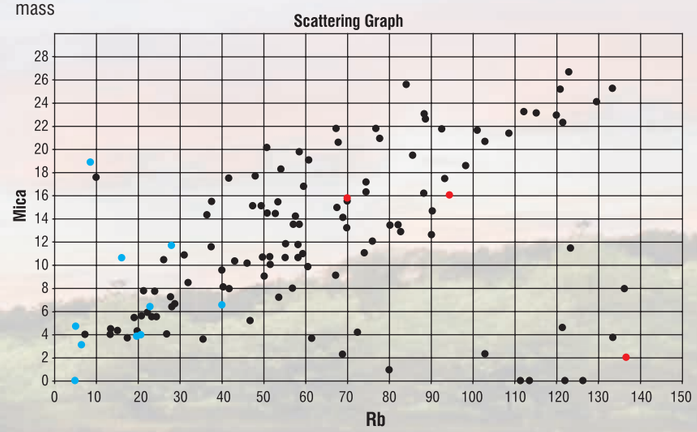
Bazhenov formation

Includes several rock lithotypes

TABLE 2. Chemical composition of micromineral forms in the rocks of the Bazhenov formation according to scanning electron microscopy

Element	Composition of the mineral phase and its characteristics
Zn	Zn content – 51…54 %, size – 5…40 μm, trace elements: S (25…29 %), Cd (1…2 %), sometimes Fe (1 %) (sphalerite?)
U	U content – 37…55 %, size – 1…3 μm, trace elements: Si (5…8 %) (coffinite?)
Fe	Fe content – 53 %, size – 10…50 μm, trace elements: S (47 %) (pyrites?)
	Fe content – 28 %, size – 5 μm, trace elements: Ti (3 %), V (13 %) (ilmenite?)
	Fe content – 67…76 %, size – 5…20 μm, trace elements: Cr (8…9 %) sometimes Ti (16 %) (chromite?)
Ba	Ba content – 51 %, size – 20…40 μm, trace elements: S (11 %), sometimes Ca (8 %) (barite?)
Pb	Pb content – 75…85 %, size – 2…4 μm, trace elements: S (9…10 %) (galenite?)
Cu	Cu content – 40...59 %, size – 10 μm, trace elements: Zn (25…35 %) (intermetallic compound)
	Cu content – 42...58 %, size – 10 μm, trace elements: S (13…22 %), Fe (6…10 %) (bornite?)
	Cu content – 72 %, size – 10 μm, trace elements: Ni (2 %) (intermetallic compound)
	Cu content – 57 %, size – 10 μm, trace elements: Sn (11 %), Co (2 %) (intermetallic compound)
	Cu content – 19 %, size – 3...10 μm, trace elements: S (36 %), Fe (19 %) (chalcopyrite?)
Au	Au content – 65…76 %, size – 3...10 μm, trace elements: Ag (5…7 %), sometimes Cu (1…2 %), Fe (1…2 %) (intermetallic compound)
Zr	Zr content – 39…56 %, size – 3…8 μm, trace elements: Hf (2 %) Si (5%) (zircon?)
Ag	Ag content –60…77 %, size – 3…10 μm (native state)
	Ag content – 42 %, size – 3 μm, trace elements: Te (33 %), S (4 %) (cervelleite?)
P33	Ce content – 20…30 %, La – 10…20 %, size– 7…10 μm, trace elements: P (10…12 %), sometimes Th (2 %) (monazite?)
	La content –21 %, Ce –16 %, size – 3…5 μm (parisite, bastnasite?)
	Y content – 20 %, size – 3…5 μm, trace elements: P (12 %), REE (up to 10 %) (xenotime?)
Sn	Sn content – 30 %, size – 10 μm, trace elements: Cu (27 %), Ni (15 %), Fe (3 %) (intermetallic compound)
	Sn content – 90 %, size – 20 μm (native state)
V	V content – 24 %, size – 10 μm, trace elements: Ti (11 %), Fe (1 %) (intermetallic compound)
Sr	Sr content – 39 %, size – 8 μm, trace elements: S (14 %), Ca (2 %), Ba (3 %) (celestine?)
Bi	Bi content – 48 %, size – 4 μm, trace elements: Cl (8 %) (bismoclite?)

FIG. 6. Correlation of rubidium content (according to the instrumental neutron activation analysis) and clay-mica minerals (according to X-ray diffractometry) in the Bazhenov rock mass



caused by hydrogen sulfide contamination, which is assumed by many researchers.

The “clastophilic” group appears to be represented by a terrigenous mineral fraction, in which, along with rock-forming minerals (feldspar, mica, clay minerals, etc.), zircon, monazite, chromite, ilmenite and other minerals are present. A direct positive relationship between the content of mica and rubidium in the rock indicates a relationship between rare alkalis and mica (Fig. 6).

Deposits of the Bazhenov formation are distinguished among surrounding rocks by increased radioactivity. This feature of the rocks is noted by all researchers. The abnormal radioactivity of these deposits is primarily due to the radioactive irradiation of uranium and its decay products (Pluman, 1971; Khabarov et al. 1980).

A significant numbers of works is devoted to the geochemistry of uranium in the rocks of the Bazhenov formation. However, the new materials obtained

FIG. 7. Histogram of uranium distribution in the rocks of the Bazhenov formation (N = 210)

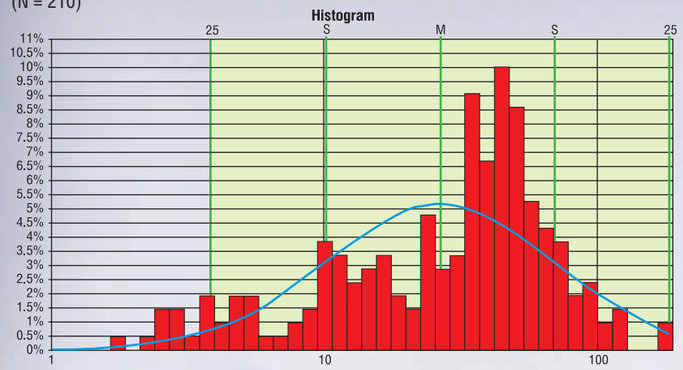
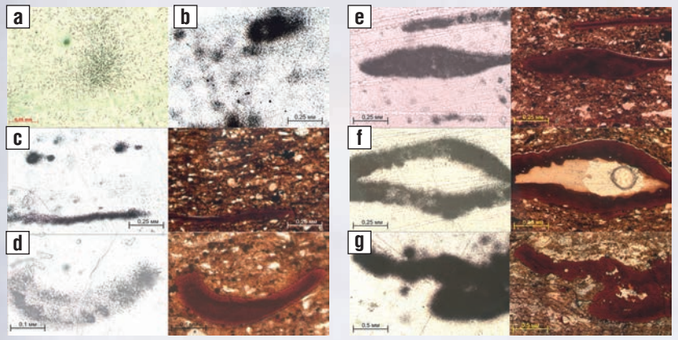


FIG. 8. Uranium distribution nature in the rocks of the Bazhenov formation according to fission radiography (f-radiography)



Note: a – in the terrigenous matrix, *b* – confinedness to local accumulations of organic matter, *c*–*g* – confinedness to valves

expand and complement the works of researchers who have studied the geochemistry of these formations, discussing at least some poorly studied issues, such as the geochemical bonds of uranium in certain types of rocks, as well as the forms of presence of this element.

Analysis of the distribution of total radioactivity within the area of the Tomsk Region (Kontorovich, 2002) showed that it is also non-constant. Radioactivity gradually fades from the west (more than 100 μR/h) to the east (40–50 μR/h).

The weighted average uranium and thorium content in the Bazhenov formation is 38 and 6 g/t, respectively, with a thorium-uranium ratio of 0.16. The total resources of uranium in the rock mass are colossal and are estimated by different researchers from 1 to 3 billion tons (I.I. Nesterov, A.R. Kurchikov, et al.).

Analysis of the histogram of uranium distribution (Fig. 7) indicates the existence of three groups of rocks according to the concentration levels of this chemical element. The first range of contents (3 to 6 g/t) most likely corresponds to the composition of the terrigenous alumino-siliceous component of the rocks, which are the petropond for the formation of the geochemical background of the sedimentation mass of the West Siberian Plate. Syngenetic uranium sorbed from seawater on organic matter and remnants of plankton and other organisms may reflect the second range of contents (10–30 g/t with a maximum of 10–14 and 20–28 g/t). The third group of uranium contents (30–120 g/t) corresponds to the range of the rocks that have undergone epigenetic transformations and in which uranium was redistributed (the maximum peak of the contents is 50–80 g/t) with possible addition of uranium from the outside.

FACTS

1 million km²

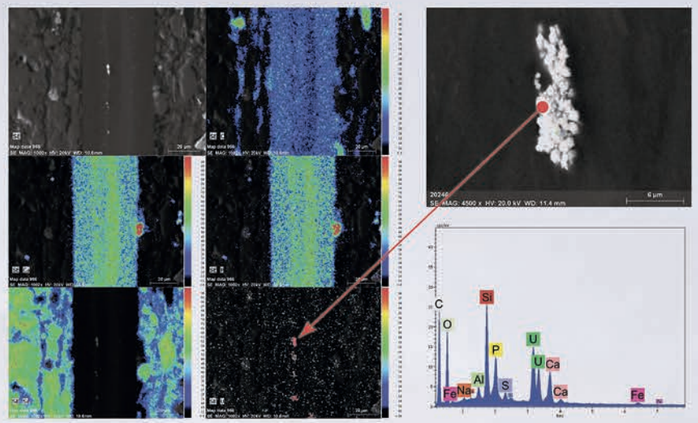
Area covered by deposits of the Bazhenov formation in Western Siberia

The study of the features of uranium distribution in the rocks of the mass carried out using the fission radiography (f-radiography) method also indicates the existence of three forms of presence of this element (Fig. 8). It should be noted that, based on the density of the tracks, uranium is distributed unevenly in the rock. Sections with a higher or lower concentration of uranium can be found. According to the form of emissions of sorbed uranium with a high density of tracks (U content of more than 30 g/t), these formations are shells and other remnants of fossil organisms.

Some researchers (Pluman, 1971; Shchepetkin et al., 1984) told about the probability of uranium concentration on these formations. The existence of U own mineral phases has been established by electron microscopic studies (Fig. 9).

It can be assumed that in the deposits of the Bazhenov formation there are two types of accumulation of ore elements (U, Mo): syngenetic (according to the scheme of sorption-biochemical models) and epigenetic, including the discharge of low-temperature fluids into the near bottom layers in the zone of influence of the Koltogorovsky rift.

FIG. 9. Main elements distribution nature (according to the data of scanning electron microscopy) in phosphate formation with thin micro-inclusions of colloform formations of uranium mineral (probably uranium oxide –coffinite?) (Sample SK-31-535)



Conclusion

According to the results of the research we can make the following conclusions:

- the content of 63 chemical elements and Corg in the rocks of the Bazhenov formation was estimated; compared with world black shales they are enriched with Ni, Zn, Mo, Ba, Gd, Dy, Au, U and some other elements, these rocks are also characterized by low concentrations of Br;
- the composition of the deposits of the Bazhenov formation is not uniform, the presence of different lithotypes of the rocks, including carbonate, alumino-siliceous, with varying amounts of kaolinite, chlorite and illite was revealed;
- an inverse correlation was established between the content of quartz and the amount of clay minerals in the rock, while a direct correlation was found between the content of Corg and the content of pyrite;
- according to cluster analysis data, several groups of chemical elements are distinguished in the rocks of the Bazhenov formation: "phosphatophile", "chalcophile" and "clastophile";
- high contents of a number of chemical elements, as well as geochemical associations are confirmed by an electron microscopic analysis: many chemical elements form their own mineral phases: barite, sphalerite, minerals Au, Ag;
- U own mineral phases are confined to the calcium phosphate mineral phases, uranium minerals have uneven distribution and are represented with own mineral species in the form of coffinite and uranium oxide.

FACTS

Up to **25** %

total amount of samples includes dolomite rich carbonate rocks

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Sergei Shcherbakov

Strong durability

Initially, Getac positioned its rugged laptops and tablets as products for military use – in order to meet the tough combat standards, the products received various certificates, including MIL-STD 810G, MIL-STD461G, ATEX, IECEx 2/22, EAC TP TC 012 / 2011. Getac equipment has successfully passed all these tests – it meets the specified standards and works efficiently in the conditions of sandstorms, storm showers and artillery shelling.

In the years that followed, Getac became interested in tablets and laptops not only for the military, but also for industrialists, geologists and oil industry workers. Entry into the civilian market was due to the excellent durability of the equipment, as well as the introduction of the company's original patented solutions and the desire to combine qualities such as security, ergonomics and compactibility into a single device. It is worth noting that Getac is the only company developing rugged components for its products, while excellent durability in no way affects the power of laptops and tablets or the speed of their work, moreover, enhanced batteries and additional batteries allow you to work with laptops for a long time.

The main advantage of Getac products over competitors is, of course, the rugged casing of its own production made of high-quality magnesium alloy. The potential vulnerabilities of fully rugged Getac laptops are reinforced with highly durable plastic – this design feature forms an integral part of the V110, B300 and X500 models. Getac devices use the unique LumiBond 2.0 technology, combining the advantages of screen glass, touch panel and LCD matrix in a single durable screen with improved readability even in bright conditions and allows the user to interact with the surface even when wearing gloves. Also, many Getac devices have built-in operation in low light conditions and support work with night vision devices.

Today Getac is ready to offer fully rugged laptops and servers based on them, as well as compact tablets based on Windows or Android. Most Getac devices are designed to operate in the most extreme conditions, but those users who do not require such a high degree of protection will easily find options for semi-rugged laptops, as well as compact and thin tablets with a lightweight casing and a security level sufficient to work, including in fire and explosive conditions.

Survival at any cost

To achieve such a high level of security, coupled with the performance and safety of the best features, laptops and tablets undergo a real crash test, which includes military tests that emulate the placement of devices in various adverse environments and circumstances – for example, one of the tests of the MIL-STD 810G standard is the placement of equipment into a chamber, where for a long time the devices are in simulated sandstorm conditions, in contrast to a usual tablet which would destruct quickly.

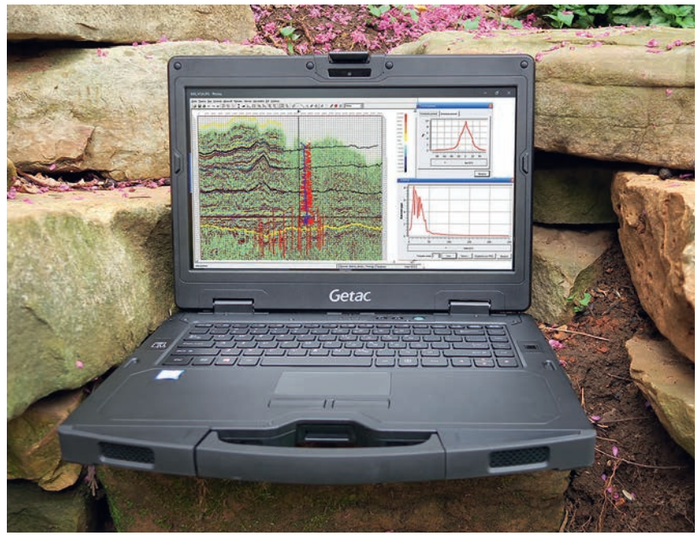
MIL-STD 810G is the benchmark standard for the military – any electronic equipment that claims to be combative must have a certificate of compliance with this standard, which includes a test of delicate electronics for operation at extremely low and extremely high temperatures, placement under prolonged shaking, applicability of moisture and water on the device, multiple drops and other durability tests.

In order to pass the military standard of reliability MIL-STD 810G, Getac laptops are subjected to rigorous tests in the laboratory for several days – the devices are dropped onto a hard surface from a height of 1.21 meters from 26 different positions, afterwards laptops are kept in a sand chamber for four hours. The testing apparatus is exposed to salt fog for four days, and as part of the temperature test, laptops are first heated in a special chamber from +30 °C to +60 °C for 4 hours, then the temperature drops sharply to -30 °C. Furthermore, army testing encompasses testing in both high and low pressure environments, the equipment is exposed to ultraviolet radiation for three days, and the devices will have to stay 10 days in a chamber with 95% humidity at +30°C. MIL-STD 810G involves many other stress tests and crash tests and Getac laptops have successfully passed all of them, proving their superiority over the models made for home use.

> Getac devices use the unique LumiBond 2.0 technology, combining the advantages of screen glass, touch panel and LCD

Taking into account the features of the Getac X500, this laptop can be used both in the Marine Corps in particularly hot zones and in the immediate vicinity of a burning oil well. However, not only the X500 and its server are capable of this, but also the rest of the Getac line, be it V110 or B300, all these models have outstanding durability. The S410, positioned by the company as a semi-rugged laptop, is slightly different, but even its degree of protection survives the average user crash test with a long off-road drive to the oil field, intensive work in low light conditions, as well as the dust and dirt of the Russian hinterland. It can withstand several crashes in the process, general careless handling and a water spill on the keyboard to boot. It is highly doubtful that such petty obstacles will slow down the Getac devices.

Talking about power – under the rugged casing there is high-quality iron. The core of all Getac laptops has Intel Core i7 processors, while Intel HD Graphics 620 is responsible for graphics. Moreover, the X500 has the ability to connect an NVIDIA® GeForce® discrete graphics controller with 1GB of allocated memory to work with really difficult graphic applications. However, in addition to the degree of protection, each model has its own characteristics and advantages.



Laptops for professionals

Despite the seemingly poor model lineup of Getac laptops, the company relied on the uniqueness of each model instead of creating many of the same type, differing only in external design features. So among the entire range the Ultra rugged X500 is the real deal, created to work in the most difficult and unpredictable conditions and involves protection from all sorts of mechanical influences. In terms of security and capabilities, the X500 is the flagship model of Getac – a mobile server can be organized on the basis of this device and it is also equipped with a special mode that increases processor power, while the Hyper-Threading system allows you to combine the responsiveness of the system to the launching of demanding applications.

A contrast to the X500 is the previously mentioned S410 – the laptop has a lower protection class and is not designed for fully-fledged combat operations, as it was not designed for this. The S410 has a clear civil professional purpose and, possessing a semi-rugged casing, the device has combined the compactibility, low weight and overall elegance of the forms, having more similar features with a regular laptop. However, the S410 has its own specific characteristics – the laptop is designed to allow the changing of the battery to a spare one instantaneously, which saves the user from having to turn off the laptop or connecting it to a charger. Getac engineers have given particular attention to the issue of data security, equipping the S410 with an entire complex of multifactor authentication, including a fingerprint dual biometric authentication, a SIM card reader and many other identity components. The S410 is also fully compatible with car docking stations, and easily receives and sends signals through the vehicle's antenna.

A more balanced option is the B300 laptop, suitable as a middle category gadget – the device is equipped with an original casing that provides complete protection without sacrificing relative compactibility and dimensions. The B300 is initially equipped with the most advanced and capacious battery, while the hardware is optimized to provide an economical mode of operation, so the system is able to work offline for a very long time. The B300 is also equipped with a similar multi-factor authentication system. At the same time, the B300 casing is airtight, and the laptop itself is able to work in any condition, having gone through army tests for durability and obtaining a certificate of compliance with army standards.

In addition to the classic triune from heavy, medium and light segments, Getac has the model V110, which is the quintessential non-standard solution. In short, the V110 is a fully rugged convertible laptop that combines the advantages of a tablet and a laptop. Despite the format, V110 has the advantages but no drawbacks inherent to the compromise models – the device is equipped with an armour-piercing casing, an advanced screen with LumiBond technology, a two-battery power scheme with the ability to promptly replace the battery, as well as data security and user recognition, while advanced solutions are integrated into the laptop's design to ensure reliable and prompt data transfer without unexpected failures and interference.

Despite Getac's fame as one of the top three manufacturers of rugged equipment, its products speak for themselves – they can claim compliance to army standards, extraordinary survivability and suitability for working in any environment, even the most extreme. According to specialists and professionals the main characteristic feature that distinguishes these laptops and tablets is the combination of iron and indestructibility that guarantees the fulfillment of tasks set in the most difficult of environments. ●

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LHG FOR HYDRAULIC FRACTURING

DEVELOPMENT OF UNCONVENTIONAL HYDROCARBON RESERVES USING HYDRAULIC FRACTURING TECHNOLOGY USING LIQUEFIED HYDROCARBON GASES AS FRACTURING FLUIDS

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ONE OF THE MOST EFFECTIVE METHODS FOR DEVELOPING OIL AND GAS FIELDS WITH COMPLICATED HYDROCARBON PRODUCTION CONDITIONS IS HYDRAULIC FRACTURING. HOWEVER, THE USE OF THE MOST COMMON WATER-BASED FRACTURING FLUIDS IS NOT ALWAYS ADVISABLE, FOR EXAMPLE, FOR UNCONVENTIONAL RESERVES, IN RESERVOIRS WITH LOW FORMATION PRESSURE, WATER-SENSITIVE MINERALS, LOW-PERMEABILITY OR WEAKLY CONSOLIDATED ROCKS. BASED ON INTERNATIONAL EXPERIENCE, IT CAN BE CONCLUDED THAT ONE OF THE MOST MODERN FRACTURING FLUIDS FOR SUCH FORMATIONS CAN BE A LIQUID BASED ON LIQUEFIED HYDROCARBON GAS OR LIGHT HYDROCARBONS. THE USE OF SUCH LIQUIDS IN THE FIELDS OF THE RUSSIAN FEDERATION HAS GREAT PROSPECTS

UDC 622.276

KEYWORDS: *hydraulic fracturing, liquefied hydrocarbon gas (LHG), unconventional reserves, Bazhenov formation, fracturing fluids.*

The experience of the last decade has shown that the main increase in reserves in Russia is due to the additional exploration of mature fields, as well as involvement in the development of unconventional and hard-to-recover reserves (HRR). This trend has been recorded by all the large oil and gas companies in Russia.

According to the estimates of the Ministry of Energy of the Russian Federation, the share of existing traditional oil fields will decline up until 2035, but the previous level of production is planned to be maintained due to the growth of production at new fields on land and shelf, as well as the development of HHR (Fig. 1) [1].

It should be noted that traditional and unconventional sites of hydrocarbon development facilities are significantly different (Fig. 2).

At present, there is no universal approach to the development of the Bazhenov formation and similar objects in the Russian Federation. For effective development of deposits with hard-to-recover and unconventional reserves, breakthrough technologies are needed that can transform these reserves into profitable and technologically-recoverable categories. One of such technologies is formation hydraulic fracturing with the main working agent-fluid (for fracturing /as a sandcarrier) based on liquefied hydrocarbon gas (LHG). LHG-based fracturing fluid is a mixture of propane and butane, presented in a liquid state. Such liquids are significantly different from the alternative, aqueous ones, containing an inorganic gas phase, such as CO_2, N_2 and their mixtures.

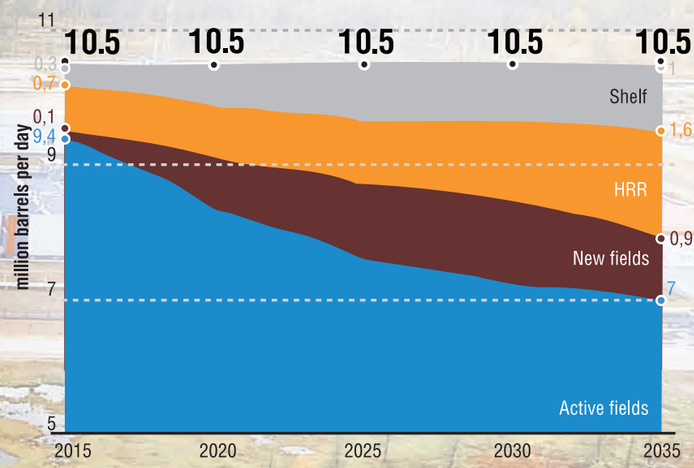
FACTS

Up until

2035

the share of existing deposits of traditional oil will decrease

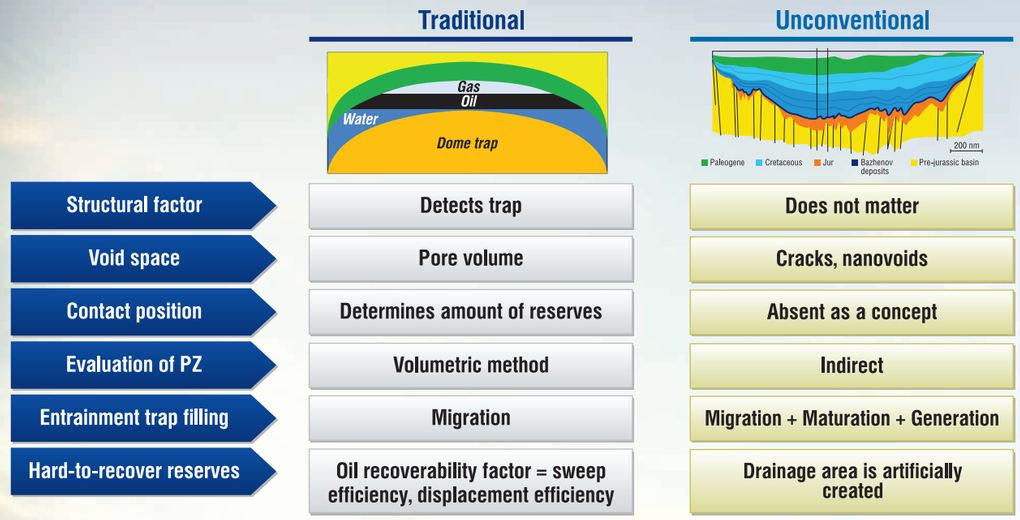
FIG. 1. The structure of oil production in Russia up until 2035



Hydraulic fracturing technology using LHG (LPG) is widespread in the United States and Canada. Currently, more than 1,500 operations have been carried out in fields with shale formations with an average tonnage of work – 25 tons/treatment [2, 3]. However, over time, the momentum of its use decreases due to the increased cost of work. The economic specifics of the countries mentioned show that the cheapest option is to drill horizontal wells with less effective but cheaper hydraulic fracturing with water-based fluids rather than with more efficient but expensive hydraulic fracturing with liquids based on liquefied gases.

The launch of this technology abroad was dictated by common sense, as well as

FIG. 2. Key differences between traditional and unconventional reservoirs



environmental requirements and restrictions. According to foreign statistics, processing of shale formations requires an average of 800–1300 m³ of water per well [2]. To begin with, such quantities of liquid need to be found, processed with chemical reagents and pumped into the formation. After treatment, there is the problem of well completion. Due to the low permeability of shale formations, the presence of swelling minerals in the formation and the increased residual viscosity of the hydraulic fracturing fluid, more than 50% of the water-based hydraulic fracturing fluid remains in the formations after they are processed. Using the example of the McCully field (Canada), it was noted that the treatment of a water-based fracturing fluid takes up to several years [2]. After extracting huge amounts of water, the problem of its disposal arises. In addition, it is worth mentioning the risks of maintaining the intactness of the well during the completion process. In most cases, for well completion after hydraulic fracturing, it is necessary to reduce the well pressure to atmospheric pressure, which significantly increases the degree of well damage [2].

FACTS

Up to

1300 m³

of water is required per well for shale treatment

FIG. 3. Characteristics of cracks formed by water-based fracturing gel

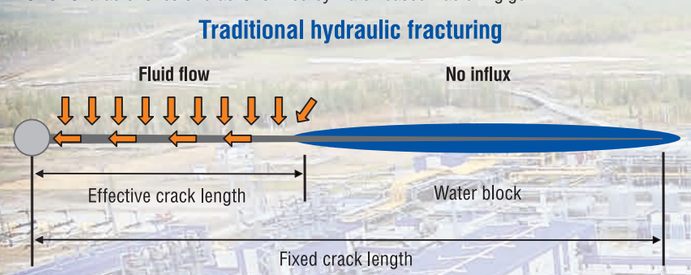
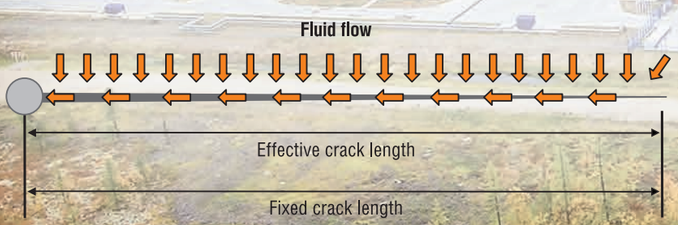
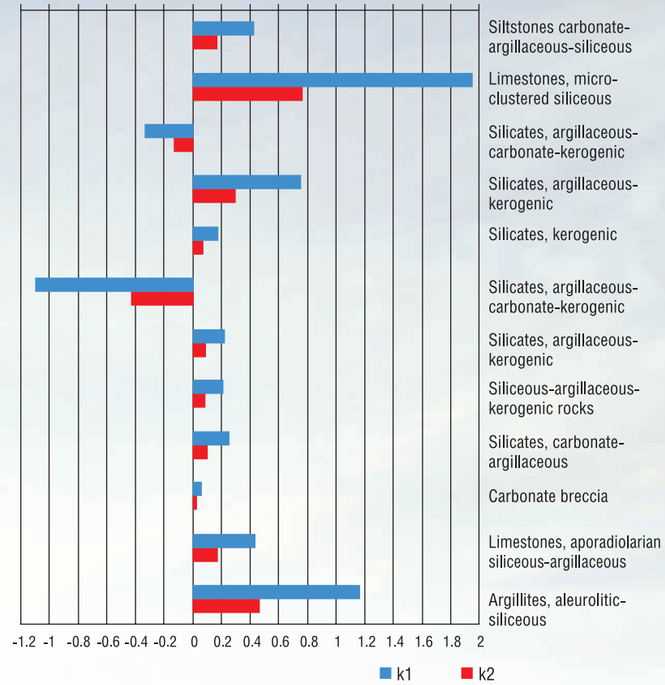


РИС. 4. Characteristics of cracks formed by light hydrocarbon fracturing gel



If you graphically compare hydraulic fracturing with a water-based fluid and hydraulic fracturing with a liquid based on liquefied gases or light hydrocarbons (Fig. 3 and 4), you can immediately understand how an additional effect is achieved. In the case with hydrocarbons, it can be seen that the effective length of the fracture is twice as large, respectively, and the flow rate of such a well will also be higher.

FIG. 5. Compatibility of water-based fracturing fluids and minerals of the Bazhenov formation



Coefficient of swelling K1 is equal to the ratio of the liquid that caused the swelling of the rock to the volume of the sample

Coefficient of swelling K2 is equal to the ratio of the liquid that caused the swelling of the rock to the mass of the sample

The residual conductivity of a crack after hydraulic fracturing with hydrocarbons is more than 90%, whereas hydraulic fracturing with water-based liquids does not exceed 40%, if we take this into account, then the effect obtained from processing becomes obvious [2].

This fact of fracture fluid blocking can be confirmed by recent studies (Fig. 5) conducted at Gubkin University, which show that the predominant amount of rocks of the Bazhenov formation swells upon contact with water-based hydraulic fracturing fluids.

FACTS

More than

1500

operations carried out on fields with shale formations with an average tonnage of 25 tons

The simplicity of well completion after hydraulic fracturing can also be assessed by comparing the characteristics of base fluids for hydraulic fracturing (Table 1) [3].

The table shows that the density of hydrocarbon gases is 2 times less than that of water, which causes a reduced pressure of the hydrostatic liquid column in the well, thus, the completion will be easier; the viscosity of propane/butane is 6 times lower than that of water, therefore, less pressure changeability is required to move the fluid through the fracture during completion; The surface tension of the gases used is 6 times lower than that of water, which implies a reduced capillary pressure when moving through a porous medium, i.e. as it progresses through the formation matrix, the fluid will experience a smaller inhibitory effect when it comes into contact with the rock and formation fluid. It is also worth noting that 1 m³ of liquefied hydrocarbon gas can be converted into 272 m³ of ordinary gas, therefore, when the well is completed, the liquid will carbonate itself, i.e. it is self-carbonated.

In general, the field of application of hydraulic fracturing technology with LHG at facilities with HRR (fields with unconventional hydrocarbon reserves), as well as fields with complicated production conditions can be represented by the following sites:

- layers of Bazhenov, Domanik, Khadum and Abalak formations;

TABLE 1. Characteristics of fluids affecting well completion after hydraulic fracturing

Liquid	Density at 20°C, g/cm³	Viscosity at 40°C, cP	Surface tension at the border with CH_4 at 20°C, dyne/cm
Water	1	0.66	72.8
Oil	0.78–0.85	1–10	21.8
Liquefied gas (propane/butane)	0.51–0.58	0.08–0.14	7.6–12.4

TABLE 2. Comparison of costs when conducting water-based hydraulic fracturing and hydraulic fracturing with LHG

Cost item	Fracturing with water-based fluids, thousand RUB	Fracturing with LHG-based fluids, thousand RUB
Processing (4 pumping units of 2500 hp each)	1 440	1 956
Fracturing fluid	390	3 900
Proppant (50 tons)	1 105	1 105
Regeneration and utilization of water	65	0
LHG regeneration	0	130
Return of the value of regenerated LHG (up to 99 % of extraction)	0	- 2 730
Total	**3 000**	**4 361**

- low-permeability gas and oil reservoirs;
- layers with water-sensitive rocks (for example, Turonian sediments, sediments of Novoportovskoe deposit, Messoyakhskoye deposit, Cherkabozhskoye formation, etc.);
- productive formations with an existing risk of a breakthrough in the upstream or lower (water or gas) interlayers (the large effective fracture length allows pumping smaller amounts of fluid and proppant agent to achieve the desired well flow rate);
- productive reservoirs with "planted" reservoir pressure;
- weakly-consolidated reservoirs (formations with limited pressure changeability during well completion).

Establishing a technological effect for ultra-low permeability formations lying in the nano- and micro-Darcy area is a nontrivial task, since the usual methods for calculating the flow of formation fluid to the well do not follow the linear-flow law. This was noted in the works by I.M. Abdurakhmanov, A.B. Gurevich, R.D. Kanevskaya, S.E. Kholodovsky, A.F. Zazovsky, A.C. Gringarten, E. Ozkan and A.B. Zolotukhin.

According to different calculation methods, the relative flow rate of the well, where the hydraulic fracturing was carried out utilizing the technology with liquefied gas, increases 1.2–2 times in comparison with standard water-based hydraulic fracturing. According to data, this indicator varies in the range – 1.3–3 times.

As for the creation of the so-called artificial reservoir (stimulated reservoir volume – SRV), its value increases by at least 25 % (in case of planar fracture during hydraulic fracturing). For branching cracks, this figure may be even greater. These results can be obtained on the basis of the geometrical parameters of the fracture.

FACTS

More than

50 %

water-based fracturing fluid remains in the reservoirs after they are processed

In accordance with the research data, the SRV indicator has a stable correlation with the KIN (oil recoverability factor) index. The increase in the artificial collector by 25 % leads to an increase in KIN by 1.6 times [4].

When comparing the cost of traditional water-based hydraulic fracturing and hydraulic fracturing using LHG, it emerged that the cost of one operation using liquefied hydrocarbon gas is 45% higher (Table 2).

UDC (Ultimate Drilling Cost) is the ratio of reduced costs for the construction of a horizontal well with a multi-stage hydraulic fracturing to the cumulative production per well. UDC for wells of unconventional hydrocarbon reserves is one of the key indicators of development efficiency. The use of hydraulic fracturing technology based on LHG allows to reduce the UDC of the sample well of the Bazhenov formation with a horizontal wellbore equal to 1500 meters and 30 stages of a multistage hydraulic fracturing by 3.3 thousand rubles per ton of oil. This effect is based on an increase in the cumulative production per well by 60 %.

The issue in regard to risks and uncertainties within the framework of hydraulic fracturing technology with LHG remains unresolved. At the moment this is the status quo:

1. Currently, there is no set of special rules and regulations in the oil industry of the Russian Federation ensuring the safe conduct of hydraulic fracturing using liquefied gases. Consequently, it is necessary either to be guided by existing regulatory documents used in the oil and gas industry, or to develop a safety rationale for typical process operation for conducting fracturing operations with liquefied gases;
2. The increased fire and explosion hazard of operations requires additional precautionary measures: taking into account the published experience of Western companies on the implementation of enhanced security measures, the development and application of the standard and rules when conducting this kind of work, the use of heat chambers and gas analyzers, the use of specialized PPE, as well as utilizing fire extinguishing agents, etc.;
3. Traditional laboratory equipment for testing fracturing fluids is not suitable for analyzing new proposed types of fluids. However, our country has accumulated sufficient potential to address this issue. Large research centres, design institutes and small innovative enterprises have vast experience and many innovative ideas for creating such equipment;
4. In respect to the development and production of chemical reagents for the production of hydrocarbon gel fracturing – production capacity and experience in the manufacture of such systems in Russia exists: Gubkin Russian State University of Oil and Gas (NRU) for several decades has conducted scientific work related to the gelation of individual hydrocarbons of various molecular weights, their mixtures, as well as natural hydrocarbons (crude oil and gas condensate) and individual hydrocarbon fractions;
5. The technology of storage, operating preparation and injection of liquefied gas implies the presence of specific equipment at the cluster pad: storage tanks, blender, proppant sail, modified sealing joints, equipment for the regeneration of rupture liquid, etc. The cost of such equipment is quite high. In most cases, significant capital expenditures and some degree of uncertainty in terms of obtaining the desired effect from the proposed innovations are serious obstacles for financing the project; 6. The implementation of this technology requires large quantities of liquefied gas. The availability of these gases is not a problem. The necessary fractions in sufficient quantities are produced at gas processing plants of the Russian Federation (31 plants). In particular, for Western Siberia the figure is more than 4.5 million tons. Also plants for the stabilization of gas condensate cannot be overlooked;
7. The lack of specialists in carrying out such work in Russia at the initial stage dictates the need to attract a sufficient number of experts from various fields of the domestic industry, however, we suggest creating in-house training for hydraulic fracturing and a culture of producing complex high-tech works.

FACTS

1 m³

liquefied hydrocarbon gas (LHG) can be converted to 272 m³ ordinary gas

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IMPROVING THE EFFICIENCY OF OIL WELL OPERATION

with small diameter lateral holes

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THE ARTICLE IS DEVOTED TO THE JOINT WORK OF NATIONAL UNIVERSITY OF OIL AND GAS «GUBKIN UNIVERSITY», AND LLC "LUKOILPERM" ON THE CREATION OF NEW TECHNOLOGIES AND EQUIPMENT FOR EFFICIENT OPERATION OF OIL WELLS WITH LATERAL TRUNKS OF SMALL DIAMETER. TODAY, DRILLING OF SMALLDIAMETER LATERAL SHAFTS FROM WELLS, THE OPERATION OF WHICH IS IMPOSSIBLE OR UNPROFITABLE, HAS BECOME WIDESPREAD IN THE FIELDS AT THE FINAL STAGE OF OPERATION. FROM 30% TO 50% OF SUCH WELLS HAVE SIDE CUTTING AT A DEPTH OF 800–1100 M, WHICH CAUSES THE NEED FOR THEIR OPERATION TO ACHIEVE THE PLANNED FLOW RATES TO PLACE PUMPING EQUIPMENT DIRECTLY IN THE SIDE SHAFT. NATIONAL UNIVERSITY OF OIL AND GAS «GUBKIN UNIVERSITY», TOGETHER WITH LLC "LUKOILPERM" HAS DEVELOPED A FUNDAMENTALLY NEW TYPES OF EQUIPMENT AND TECHNOLOGIES FOR THE EFFICIENT EXPLOITATION OF OIL WELLS WITH LATERAL TRUNKS OF SMALL DIAMETER. THESE ARE DOWNHOLE PUMPING UNITS WITH A CABLE ROD (DPU CR) AND JET PUMPING UNITS (GPU), AS WELL AS A SET OF SOFTWARE TOOLS FOR THE SELECTION OF EQUIPMENT TO THE WORKING CONDITIONS IN THE WELL. EQUIPMENT HAS BEEN PILOTFIELD TESTED AND TRANSLATED INTO COMMERCIAL OPERATION. THE ARTICLE PRESENTS THE RESULTS OF WORK ON THE CREATION OF EQUIPMENT COMPLEXES, ITS DESCRIPTION AND APPLICATION TECHNOLOGY, THE RESULTS OF BENCH AND FIELD TESTS

Ключевые слова: *эксплуатация нефтяных скважин, технологии и оборудование, боковые стволы малого диаметра, завершающая стадия эксплуатации, насосное оборудование.*

UDC 622.24.05

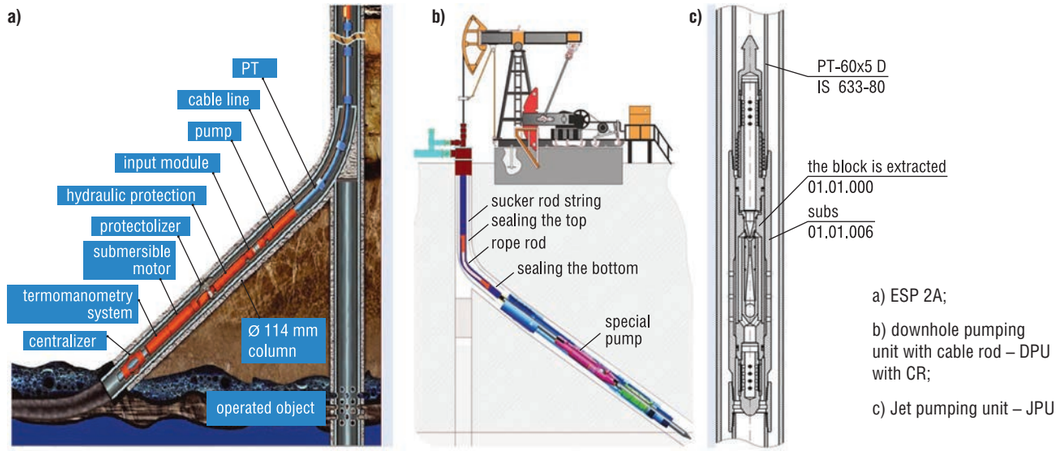
At present, a significant number of fields in the Russian Federation are in the final stage of operation therefore to reduce operating costs the drilling of small diameter lateral holes is widespread in wells where operation is inexecutable (it is impossible to eliminate the leakage of the cement stone and the flow string or to lift pumping equipment after downhole submersion) or unprofitable because of the high water content.

From 30% to 50% of such wells have kickoffs at a depth of 800–1100 m, which makes it necessary to place pumping equipment directly into lateral holes during its operation in order to achieve planned production rates [1].

The operation of wells with lateral holes is complicated due to small internal diameters of flow strings (89 mm and 102 mm), high rates of curvature, reaching 14–19° per 10 m, large deviations from the vertical position (55–70°). Consequently, this does not allow for the use of standard pumping equipment [2].

Currently, there are several types of specially-designed pumping equipment for the efficient operation of wells with small diameter lateral holes, which have already passed field tests and have been put into commercial operation, or are in the final stage of testing. This equipment is presented below (Figure 1):

FIG. 1. Equipment for the operation of wells with small diameter lateral holes



a) ESP 2A;

b) downhole pumping unit with cable rod – DPU with CR;

c) Jet pumping unit – JPU

- Small-sized units of electric centrifugal pumps (ESP 2A and ESP 3);
- Downhole pumping units with cable rod (DPU with CR);
- Jet pumping units.

ESP 2A and ESP 3 are currently produced by Novomet LLC, Almaz LLC and Alnas LLC.

Pump stages for small-sized ESPs were created taking into account the wide experience of ESPs of other dimensions, as a result of which ESP 3 and ESP 2A turned out to be quite successful and energy-efficient – their efficiency reaches 60% (Novomet company).

The head pressure is small – 2.5–2.7 m at a standard rotation frequency (2910 rpm), therefore, in order to increase the pressure, high-speed permanent magnetic motors (PMM) are used: shaft speed varies from 4500 to 6000 rpm.

Despite the use of high rotational speed, the length of the pumping unit, especially when using the gas separator, can reach 7.3–22.2m (PMM length is from 2.5 to 7 m + the length of the pump is from 4 to 14 m + the length of the gas separator is 0.8–1.2m), which creates huge problems for the operation of such equipment in small diameter lateral holes, which have large rates of curvature (small deviation radii).

The main disadvantages of small-sized pump stages are hydraulic channels of small-sized flow sections in impellers and guide vanes, which can lead to their clogging by salts and mechanical impurities, and also they require the use of gas separators (GS) in the presence of free gas [3].

The use of small-sized ESPs in LUKOIL-PERM LLC is not widespread due to the high cost of equipment and insufficiently high production rates of wells with small diameter lateral holes.

A downhole pumping unit with a cable rod (DPU with CR) is the equipment that has been actively used in recent years for well operation with small diameter lateral holes in the Perm region.

The downhole pumping unit with a cable rod was developed at Gubkin Russian State University of Oil and Gas (NRU) at the Department of Machinery and Equipment of the Oil and Gas Industry in cooperation with LUKOIL-PERM LLC. The unit (see Figure 1b) includes: a drive in the form of a beam unit (hydraulic drive, chain drive or another type of drive), a special-purpose sucker rod pump, cable rod strings, installed at the place of the intense set of curvature [4, 5].

Creating a new type of equipment with its own application technology is not an easy task. Works on the creation of DPU with CR began in 2011 and the following have been developed:

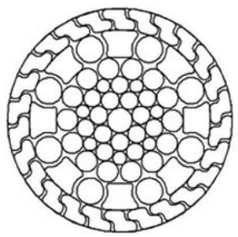
- Specifications for closed construction cable for the production of the cable rod;
- A set of equipment for connecting the cable rods with the pump plunger and the rod strings;
- Special pumps for stretching the cable rods when the plunger moves downwards;
- Software package for the selection of DPU with CR for the well parameters, incoming software complex "Autotechnologist";
- Guidance document, including requirements, instructions and recommendations for working with cable rods.

The cable rod is the most important element of the entire pumping unit. Cables, when used as rod strings, should have sufficient strength and be elastic, and closed construction cables have such properties. Numerous laboratory and experimental field tests of cables of various designs made it possible to develop the Specifications for closed construction cables for the production of the cable

TABLE 1

Diameter of cable, mm	Estimated weight of 1 m og lubricated cable, kg	Tensile strength of the cable, kN, not less
1	2	3
16,0	1,4	206
20,0	2,3	362
22,0	2,6	371
25,0	3,5	487
28,0	4,4	627
30,0	5,1	697

Characteristics of the cable			Design
Diameter, mm	Number of pieces		
	layers	wires	
16,0	5	78	Z25 + X9 / Ø9 + 36(14+7/7+7+1)
20,0	5	78	Z26 + X8 / Ø8 + 36(14+7/7+7+1)
22,0	5	83	Z29 + X9 / Ø9 + 36(14+7/7+7+1)
25,0	5	84	Z28 + X10 / Ø10 + 36(14+7/7+7+1)
28,0	5	91	Z32 + X12 / Ø12 + 36(14+7/7+7+1)
30,0	6	110	Z29 + 13 / Ø13 + Ø19 + 36(14+7/7+7+1)



rod [6]. Characteristics of the closed construction cables for the production of the cable rods are presented in Table 1.

The technical conditions stipulate the release of cable rods of three versions (Figure 2): standard (group K1); corrosion-resistant (group K2), with galvanized coating of all wires; corrosion-resistant (group K3), with galvanized coating of all wires and external polymer coating Poketon M630F.

Bench laboratory tests of samples of a cable rod with a polymer coating showed that the polymer coating serves not only as protection against the corrosive effects of formation products, but also protects the cable against fluffing as a result of compressive loads. During installation of the pump plunger or during operation (due to the large curvature, sediment deposits, wedging of the pump plunger, etc.), compressive loads may act on the cable rods, leading to loss of cable stability and fluffing. During further operation of the unit, due to the variable bending at the place of fluffing, the wires of the cable rod break and disconnection occurs. Figure 3 shows the results of testing samples of cable rods with and without polymer coating.

The cable rod with polymer coating passes pilot testing on the fields of LUKOIL-Perm LLC. Figure 4 shows the installation of a cable rod with polymer coating into the well; a geophysical cable hoist and a system of rollers are used to lower the cable rod.

The most important elements of the cable rod are the embeddings, which serve to connect the cable

FIG. 2. The Cable Rod

a) with polymer coating (no fluffing);
b) without polymer coating (fluffing occurs)

FIG. 3. Cable rod compression test

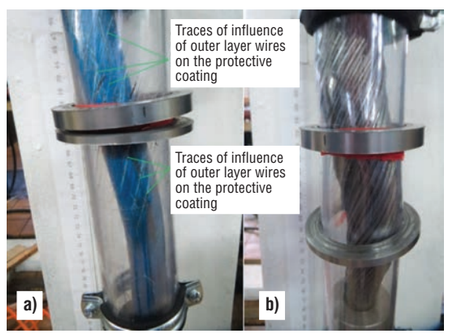
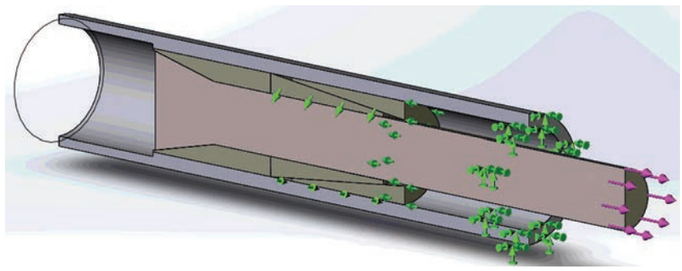


FIG. 4. Installation of a cable rod with polymer coating into the well

FIG. 5. Destruction of cable rods in the embedding and the embedding casing

FIG. 6. 3D model of cable rod embedding for durability calculations in the Solid Works software package



with conventional rod strings and must ensure uniform loading of all the wires of the cable. The embedding consists of a casing where two conical hubs are located, in one hub the cable is fluffed out using wedges, in the second one is fitted with wedge liners that compress the cable along the outer surface [7, 8].

The first experimental field tests showed that in a number of cases the cable itself in the embedding was destroyed, as well as individual embedding elements (Figure 5).

To enhance the design in the SolidWorks software package, durability calculations of all the elements of the embedding were carried out, and their best geometrical parameters were selected to ensure minimum contact pressure in the cable rods. Figure 6 shows a 3D model of a cable rod embedding for conducting durability calculations.

For normal operation of the cable rod, specially-designed pumps are used, which provide the tensile load on the cable rods when the pump plunger moves downwards. Currently, the DPU with CR has a special sucker rod pump SPeaR, produced by Elkam-Neftemash (Figure 7a). The disadvantage of this pump is the dependence of the tensile load on the dynamic fluid level in the well. The Department of Machinery and Equipment of the Oil and Gas Industry of Gubkin Russian State University of Oil and Gas has developed a pump with a discharge chamber NNRK, which provides an increase in the load on the lower part of the rod string and prevents constriction of the cable rod (Figure 7b) [9].

Three prototypes of discharge chamber pumps NNRK 44/27 were manufactured at NKNM LLC and are currently undergoing pilot testing in oil wells at LUKOIL-Perm LLC in accordance with the approved methodology. Figure 9 shows the process of installing the discharge chamber pump NNRK 44/27 and the dynagraph of the pump.

The cable rod, having high durability, has a conventional modulus of elasticity below the elastic modulus of a standard rod, which increases its elongation and reduces the pump flow, in addition, for operation in the lateral hole, it is necessary to install the cable rod in the place of the most intensive curvature clusters. This paved the way for the creation of a method for selecting the DPU

FIG. 7. Specially-designed pumps used in DPU with CR

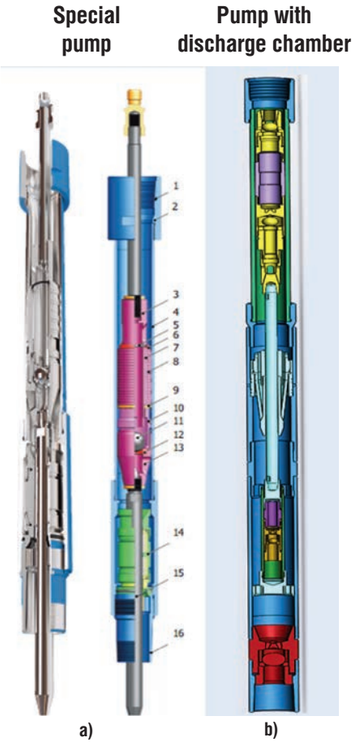


FIG. 8. Installation of the discharge chamber pump NNRC 44/27 and the dynagraph of its work

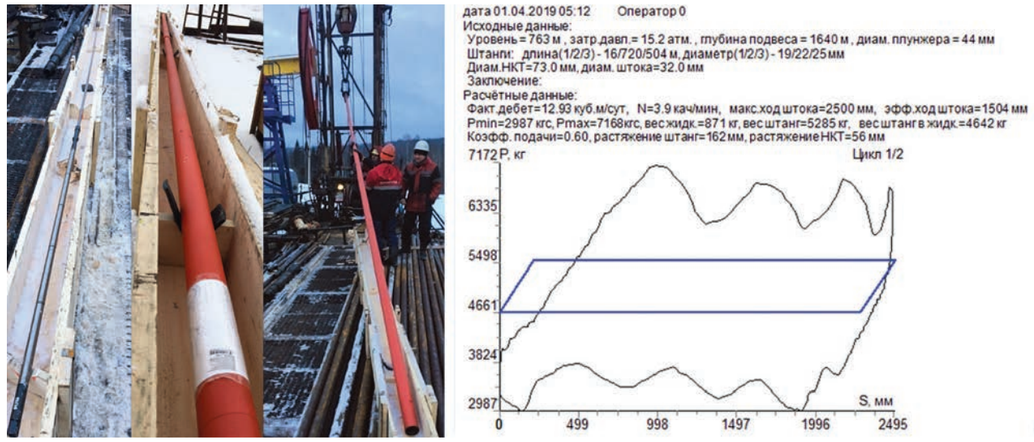
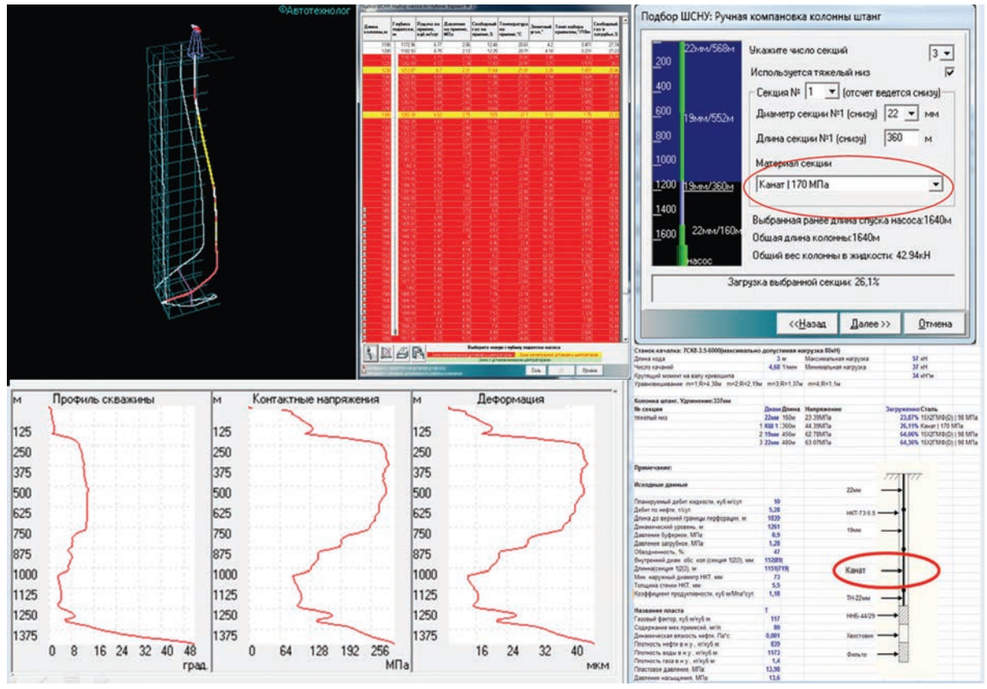


FIG. 9. Selection of DPU with CR based on well parameters using the “Autotechnologist” software package



with CR in order to be compatible with well conditions, and this was implemented in the software package of “Autotechnologist” [10].

The program allows you to build a well profile, and gives recommendations on the place of installation of the cable rod. It also displays information on bearing resistance and deformations (wear and tear) of the tubing string from friction of the cable rod, calculates the best design of the cable rod and installs parameters that provide the required well flow rate (Figure 9).

Calculations, which are confirmed by the practice of using DPU with CR, show that the use of a cable rod reduces the intensity of tubing wear and tear by 50–100 times in wells with complex inclinometry.

At present, DPU with CR are used for industrial operation in more than 85 wells with lateral holes in the companies: PJSC NK LUKOIL (LUKOIL-PERM LLC, LUKOIL-Western Siberia LLC); PJSC NK ROSNEFT (Samatlorneftegaz, Samaraneftegaz, Orenburgneft, Udmurtneft); UK Sheshmaoil LLC; ZARUBEZHNEFT; Ural-Oil LLC.

TABLE 2

No.	Company name	Number of wells, pcs	Maximum runlife of CR per day
1	LUKOIL-Perm	74	1551
2	Samaraneftegaz	12	1394
3	Samotlorneftegaz	9	148
4	Bashneft	2	756
5	Udmurtneft	2	369
6	Sheshmaoil	7	760
7	Zarubezhneft	2	1255
8	Ural-Oil	2	486

Besides this, there are pilot tests in other oil producing companies in Russia and abroad. The runlife of the cable rod is influenced by various factors, such as the curvature of the well, the deviation of the well from the vertical position, the length of the cable rod, the presence of asphaltene sediments and others. [11]. Table 2 presents data on the runlife of the cable rod. Low values of the runlife in several production companies are related to the fact that DPU with CR was mounted in 2017 and 2018.

It should be noted that the use of pumping units with cable rods allowed to increase oil production from wells with small diameter lateral holes by an average of 2.0–3.5 tons per day and also allowed to augment the average time before failure of rod strings and production tubing from 180 to 500 days.

Another technology for the extraction of oil from wells with small diameter lateral holes, developed by Gubkin University together with LLC LUKOIL-Perm is the jet pumping unit (JPU).

The advantages of using jet pumps include:

- small dimensions (the length of the pump does not exceed 1 m with a diameter of 48 mm), which makes it possible to use such equipment even in very complicated inclinometry of small diameter lateral holes;
- a wide range of flow rates and the ability to consistently collect formation fluid with a high content of free gas, smoothly adjust and maintain the bottom hole pressure and flow rate at a given level by controlling the pressure and volume of the injected working agent;
- simplicity of design and the absence of moving parts ensures a high turnaround time, the wearing part of the pump – the nozzle – can be made from wear-resistant materials;
- the possibility to use the pump as a freely discharged unit, i.e. nozzles can be changed without lifting the tubing string;
- pump rate depends very little on viscosity (up to 500 cP).

Small diametrical dimensions allow the use of jet pumps in wells with lateral holes and production strings with a diameter of 102 mm (internal diameter 89 mm), with a curvature rate of more than 20° per 10 m.

Figure 10 shows the general description of the jet pump unit. The power liquid is water from the FPM system. The power liquid is supplied to the jet pump through the tubing string, the formation products enter the wellhead through the annulus, and the packer is used to separate the annulus [12, 13].

FIG. 10. General plan of the jet pumping unit for oil production from wells with small diameter lateral holes

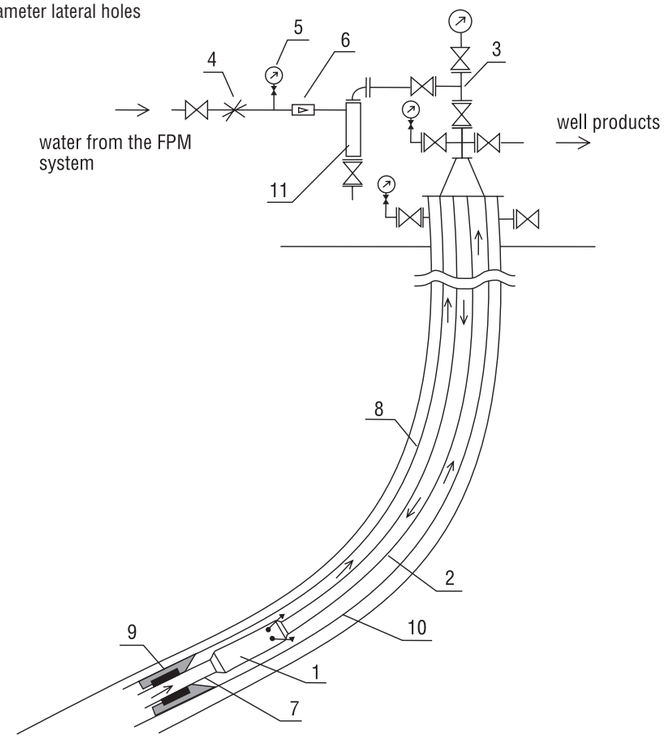
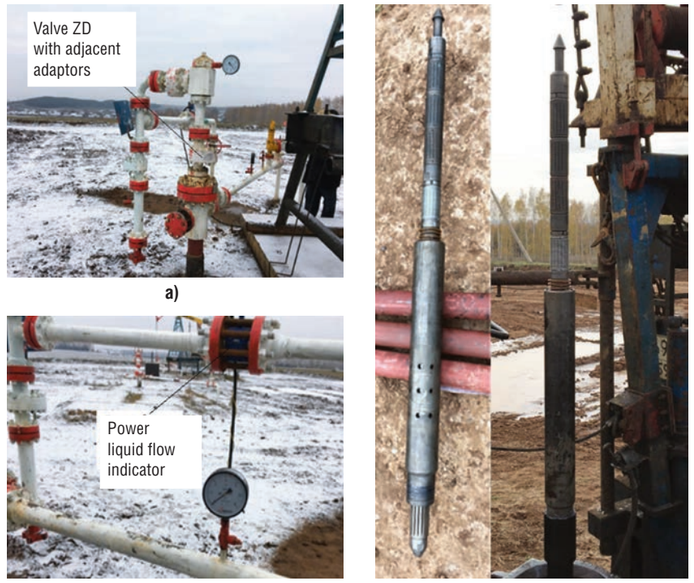


FIG. 11. Equipment for working with jet pumping units



a) wellhead equipment with replaceable adaptors of the production well;
b) flow indicator of power liquid (injection well);
c) jet pump before the descent and at the wellhead

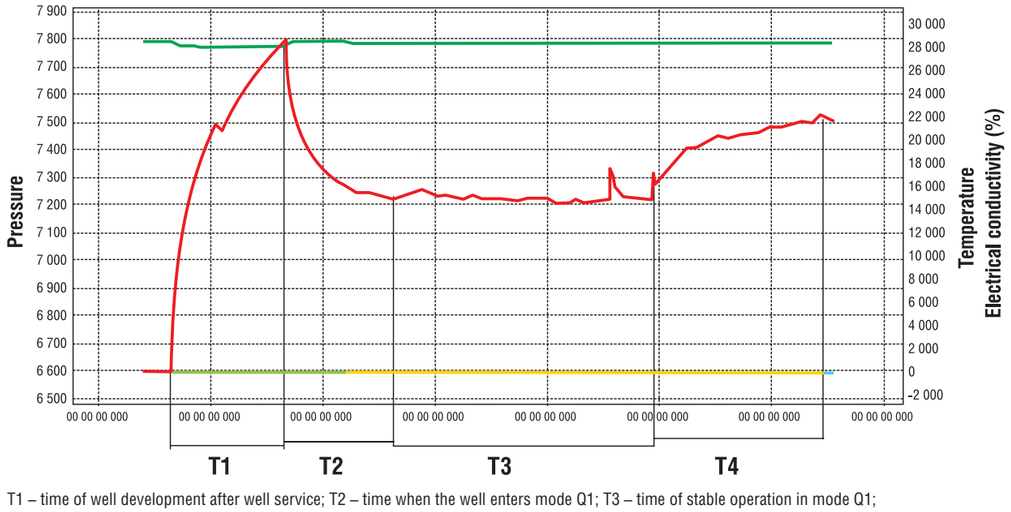
Figure 11 shows the jet pump, its installation at the wellhead and the arrangement of the production wellhead, equipped with the installation of a jet pump and an injection well with water which is used as the power liquid.

Monitoring of the jet pump is carried out by way of a depth gauge installed in the sub-packer zone (Figure 12 shows the readings of the depth gauge while the jet pump is operating), wellhead gauges and flow gauges measuring the flow of the power liquid. Regulation of the unit is carried out by a replaceable adapter that regulates the flow of the working liquid. Replaceable adapters are placed into the disk of the sliding valve (type ZD) installed in the wellhead equipment of the well where the jet pumping unit is installed.

The main elements of the jet pump are the nozzle and the mixing chamber. The nozzle undergoes considerable strain during operation (the flow rate of liquid from the nozzle may exceed the speed of sound), which can lead to the destruction of the nozzle flow section. Conducted numerical studies in the Flow Simulation of the Solid Works software package made it possible to enhance the design of the nozzle and the mixing chamber. It was proposed to use solid alloy VK-6. Figure 13 shows the process of numerical modeling of the pressurized state of the nozzle and elements of the jet apparatus (nozzle and mixing chamber made of solid alloy VK-6).

In order to install the jet pump, the “Jet pump” calculation software was developed as part of the “Autotechnologist” software package, which allows to determine the installation based on well parameters.

FIG. 12. Readings of the depth gauge during operation of the jet pump



T1 – time of well development after well service; T2 – time when the well enters mode Q1; T3 – time of stable operation in mode Q1;
T4 – time of well transfer into supply mode Q2

FIG. 13. Pressurized state of the nozzle and the elements of the jet apparatus made of solid alloy VK-6

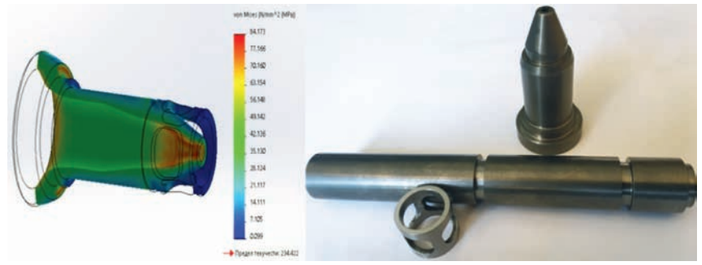
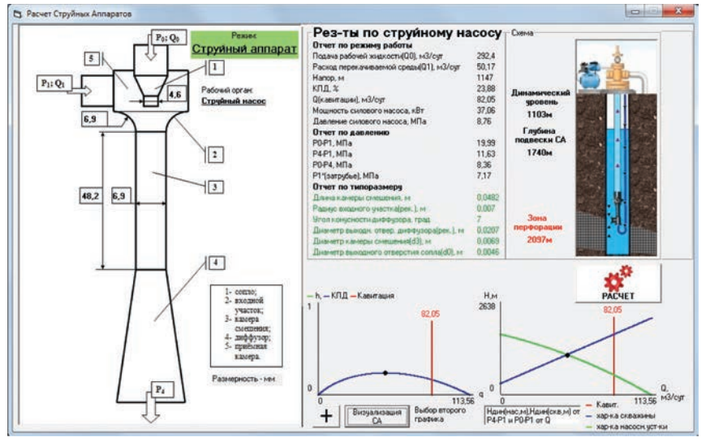


FIG. 14. The result of determining the nominal sizes of the main parts of the jet pump



When selecting the installation of the jet pump in the “Autotechnologist” software, the following are determined based on well parameters (Figure 14) [14]:

- flow of working (ejecting) fluid,
- consumption of the pumped (ejected) medium,
- head pressure of jet pump,
- output of the power-operated pump,
- pressure of the power-operated pump,
- Efficiency rate of jet pump,
- nominal sizes of the main parts of the jet apparatus.

At present as part of pilot testing, six wells with small diameter lateral holes are operated by jet pumping units in the fields of LUKOIL-Perm LLC. The maximum runlife before failure of the jet pump was 562 days. In 2019, another 11 sets of jet pumping units are planned to be introduced.

The use of jet pumping units allowed to increase the flow rate (crude oil) of wells with small diameter lateral holes by 3.0–5.2 tons per day, while the cost of equipment of such wells is about 3–4 times lower than when using small-sized electrical submersible pump (ESP) units.

As a result, as of now Russia has developed unique new technologies and equipment packages which make it possible to effectively operate marginal and medium production wells with small diameter lateral holes, and this in turn makes it possible to obtain additional oil production at fields that are in the final stage of operation consequently increasing oil recovery at these fields. ●

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VOLUMETRIC PUMPS OF NOVOMET – new solutions for oil production

THE RESERVES OF LIGHT CRUDE OIL, BOTH IN RUSSIA AND IN THE WORLD, ARE BECOMING LESS AND LESS EVERY YEAR. ACCORDING TO EXPERTS OF THE OIL AND GAS INDUSTRY, THE WORLD RESERVES OF VISCOUS CRUDE OIL SIGNIFICANTLY EXCEED THE RESERVES OF LIGHT CRUDE OIL, AND CONSTITUTE MORE THAN 70% OF ALL RESERVES. PRODUCTION OF VISCOUS CRUDE OIL REQUIRES AN UNCONVENTIONAL UNIQUE APPROACH. WHAT SOLUTIONS DO RUSSIAN EQUIPMENT MANUFACTURERS OFFER?

UDC 622.276

KEYWORDS: *volumetric pumps, oil production, high viscosity crude oil, mining installation, submersible pump.*

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As the growth of light crude oil production continues to increase, the proportion of heavy crude oil in terms of hydrocarbon reserves will increase. In many industrialized countries of the world heavy, viscous oil is considered as the main base for the development of oil production in the upcoming years. According to forecasts of leading world analysts, the dynamics of producing such raw materials in the future will have a positive trend.

In other words, in the near and distant future, the production of viscous oil is of key importance.

Traditional methods of producing viscous oil

Traditionally, under such conditions, the installation of beam pumping units and screw pumps is carried out. However, the application of the former at the initial stage of construction of the site and the placement of equipment requires large capital expenditures. In regard to the latter, it is necessary to select a type of elastomer for each well, which increases the product range and the number of errors during the selection process. The use of rods for the drive also limits the use of these installations in horizontal wells.

The proposed solution

One of the ways to solve the problem is to use volumetric pumps driven by a submersible electric motor. Firstly, there is no need to build up the infrastructure of the well, and secondly, in the absence of an elastomer, individual selection of a pump is not required.

The problems arising from the production of viscous oil by traditional methods: using plunger or screw pumps can be solved by using a volumetric submersible pump that would receive energy from a submersible electric motor. A multistage vane pump of original design [RF Patent No. 2495282] with the arrangement of plates in the stator was chosen as the solution. A general view of the pump stage is shown in Fig. 1.

The volumetric Rotary Displacement Cylindrical Pump of the vane type (hereinafter referred to as RDCP) is assembled and is shown in Fig. 2. The advantages of this pump over plunger pumps and screw type pumps are as follows:

- no elastomers are used;
- the pump can create almost any desired head pressure (by selecting the required number of pump stages);
- can be installed in horizontal sections of the well;
- tests carried out showed the possibility of its use for pumping high viscosity crude oil, up to 5000 cSt.

FIG. 1. General view of the RDCP stage

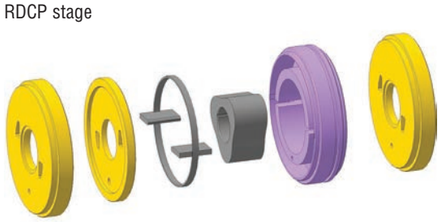


FIG. 2. General view of the multi-stage vane pump

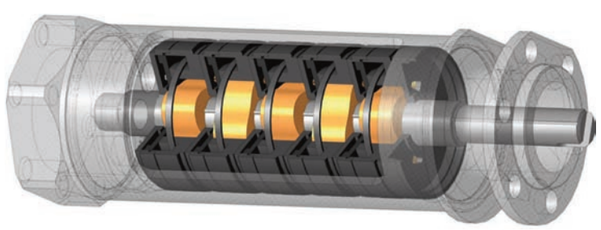


FIG. 3. Head and rate specifications of the stage of RDCP5 based on water (750 rpm)

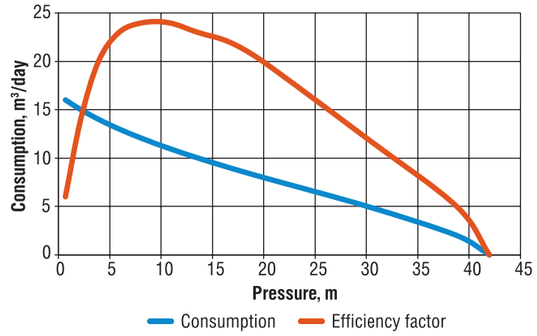


FIG. 4. Head and rate specifications of the stage of RDCP5 based on a fluid with a viscosity of 100 cSt (750 rpm)

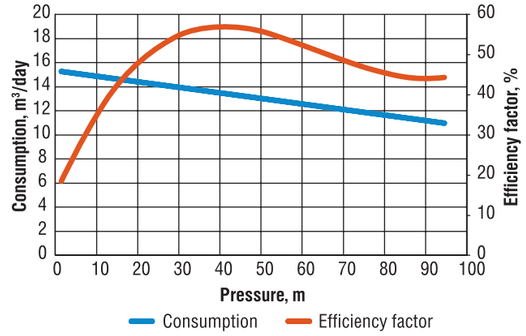


TABLE 1. Characteristics of RDCP5

Flow rate, m³/day	**5–15**
Speed range, rpm	**500–1000**
Nominal speed, rpm	**750**
Corrosion resistance	**Any type, including for SSC**
Recommended fluid viscosity, cSt	**30–5000**

Successful tests of the prototype led to the development and manufacture of this type of pump in 2 versions. JSC Novomet Perm produces in size RDCP-5 and RDCP-5A. The characteristic of each pump is presented below.

Characteristics of RDCP5-10

Initially, this pump was designed and manufactured in size 5 for marginal wells. Together with a 117mm low-speed electric motor, the RDCP5-10 can be used for flow strings from 140mm.

Characteristics of the pump are presented in Table 1.

This pump has passed all factory tests, including resource tests with sand. To increase the runlife of the pump, elements are made of wear-resistant materials.

Also, the pump has passed pilot tests in various oil companies, both in Russia and abroad.

It is worth noting that volumetric pumps have the best results when working based on a viscous fluid. The tests carried out confirmed this. Head and rate specifications at different viscosities, in terms of one pump stage, are shown in Fig. 3, 4. It can be seen that as the viscosity of a liquid increases, the head pressure increases monotonically with the same flow rate (due to a decrease in leakage through the gaps). The efficiency factor of the viscosity of the fluid also changes monotonically – it increases as the viscosity goes up.

Characteristics of RDCP5A-50

In the continuation of the development of this type of pump, the RDCP5A was developed with a flow rate of up to 50 m³/day.

Like its predecessor, the pump in this category has passed all factory tests and is at the stage of conducting pilot tests in various companies in Russia and abroad.

As in RDCP5, the elements of the pump stage are made of wear-resistant materials.

A brief description of the pump is presented in Table 2.

Tests on different fluids confirmed the best performance of the pump on fluids with greater viscosity.

Head and rate specifications at different viscosities, in terms of one pump stage, are shown in Fig. 5, 6. It can be seen that as the viscosity of a liquid increases, the head pressure increases with the same flow rate (due to a decrease in leakage through the gaps).

From this it follows that when working based on a viscous fluid, we need to use a smaller number of pump stages, as a result, the cost of the pump will be lower.

Design of RDCP

The assembled unit is standard, just like ESP units, the only difference is that a low-speed electric motor with a rotational speed of 100–1500 rpm is used.

TABLE 2. Characteristics of RDCP5A-50

Flow rate, m³/day	**20–50**
Speed range, rpm	**500–1000**
Nominal speed, rpm	**1000**
Corrosion resistance	**Any type, including for SSC**
Recommended fluid viscosity, cSt	**30–5000**

FIG. 5. Head and rate specifications of the stage of RDCP5 based on water (1000 rpm)

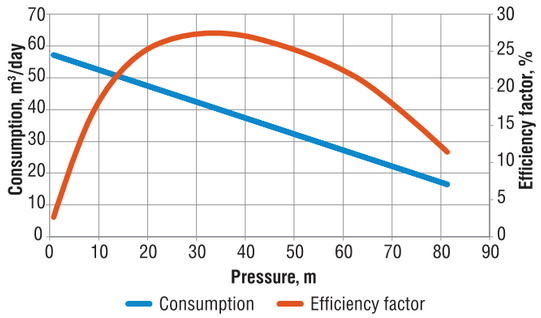


FIG. 6. Head and rate specifications of the stage of RDCP5A based on the liquid viscosity of 100 cSt (1000 rpm)

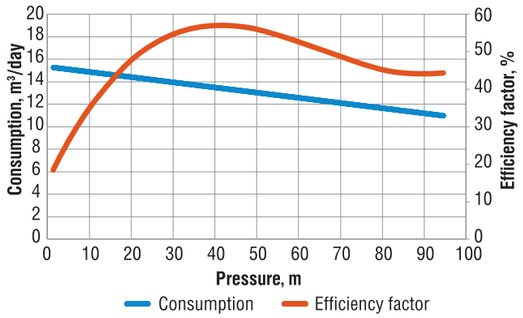
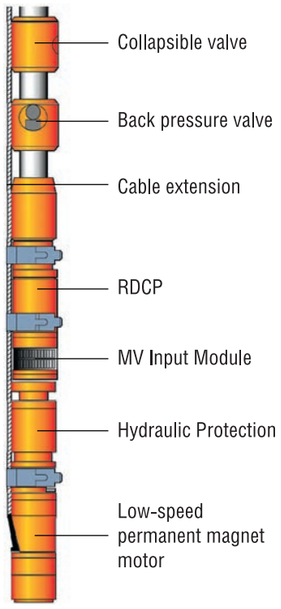


FIG. 7. Design of RDCP



The main elements of the assembled unit are shown in Fig. 7.

Power comparison of RDCP, ESP and PMM in terms of frequency of rotation

The analysis of the comparison of the power of RDCP, ESP and PMM in terms of rotation frequency (see Fig. 8 and Fig. 9).

As you can see, the operating frequency zone of the ESP is limited by the power of the electric motor (right edge) and must be created by pressure – at least 20% of the nominal one (left edge).

At these limits, the range of variation of the pressure is 30%.

The RDCP is operable in a wide frequency range, the upper edge is limited by the durability of the design of the steps – 1000 rpm, the lower edge is limited by the flow rate – 100 rpm (see Fig. 9). In this case, the power of the electric motor is sufficient in the entire range of rotational frequencies.

At these edges, the range of change in the flow rate of RDCP is 3 times larger than that of ESP (see Fig. 9).

Implementation experience with submersible electric motors

Today, we have extensive experience in implementing RDCP in various companies in Russia and abroad.

Table 3 shows RDCP developments in different companies (data as of May 20, 2019).

We would like to highlight the introduction of the equipment at the East-Messoyakhskoye field.

FIG. 8. Dependence of head pressure, power of ESP and power of PMM in terms of rotational speed

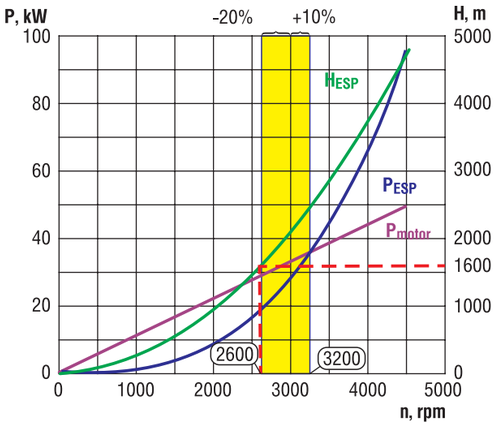


FIG. 9. Dependence of head pressure, power of RDCP and power of PMM in terms of rotational speed

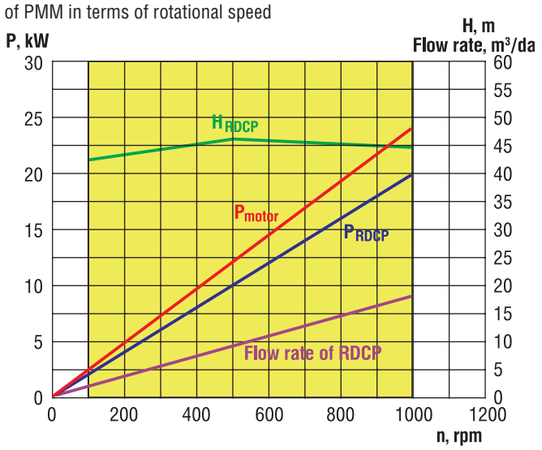


TABLE 3. Implementation experience of RDCP

	Company	Production date	Status	Runlife
RDCP5-10	OMV Petrom (Romania)	**20.07.2015**	In operation	**1400**
	OMV Petrom (Romania)	**20.02.2017**	In operation	**819**
	OMV Petrom (Romania)	**16.02.2018**	In operation	**458**
	JSC Messoyakhneftegaz	**12.09.2017**	Dismantled 19.08.2018	**341**
	LLC Lukoil Perm	**22.03.2018**	In operation	**425**
	PDVSA (Colombia)	**26.09.2018**	In operation	**236**
RDCP5A-50	JSC Messoyakhaneftegaz	**24.06.2018**	Dismantled 22.01.2019	**215**
	OMV Petrom (Romania)	**25.07.2018**	In operation	**300**

TABLE 4. Characteristics of RDCP with above-ground drive unit

Size	5	5A
Speed range, rpm	100–400 (limited by drive unit)	
Flow rate, m³/day	1–6	2–20
Recommended viscosity	30–5000	30–5000

It is known that this field is complicated due to the removal of numerous mechanical impurities up to 1600 mg/l. The viscosity of the liquid is about 300 cSt and the temperature of the liquid is 16 °C.

Even in such conditions pilot tests were successfully completed.

RDCP is the solution for the replacement of screw pumps driven by drill rods

RDCP can be used to replace screw pumps driven by drill rods.

This solution will reduce the risk of failure to launch (as there is no elastomer, fracture initiation is less likely). Below is a brief description of the RDCP with rotation from the top drive.

The design of the unit is shown in Fig. 10.

The installation procedure is standard:

1. Installation of the anti-backing anchor with MS RDCP and the descent of the unit on tubing;
2. Fixing the anti-backing anchor by turning the tubing;
3. Descent of the pump rods with a splined anchor to connect with MS RDCP;
4. Adjustment of rods on the opening for connection with the drive unit.

Given the positive operating experience of this type of pump at high speeds, the operating time of this equipment at speeds of 100–400 rpm will only increase.

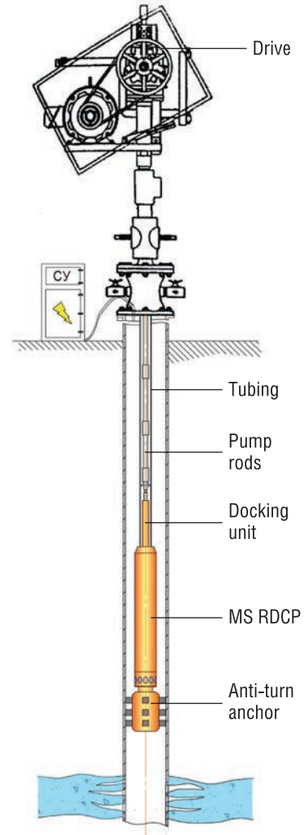
Conclusion

Summarizing the above, we would like to note:

For the production of viscous oil, JSC Novomet Perm offers an original design: the volumetric Rotary Displacement Cylindrical Pump (RDCP), which has several advantages over other types of volumetric type units. By selecting the required number of pump stages, this pump can create almost any desired head pressure and can be used in horizontal sections of the wells.

The head pressure of RDCP on a viscous fluid is much higher than that of similar marginal centrifugal pumps. In contrast, the head pressure of this pump amplifies with increasing viscosity. Thanks to the new equipment, it will be possible to reduce the cost of oil production in general, especially for the production of viscous oil.

FIG. 10. RDCP design with a drive unit from above-ground electric motor



The wide speed range control allows you to adjust the flow rate to a large extent in contrast to ESP.

The absence of an elastomer in the pump design allows for a simpler selection of a pump for wells.

Due to the absence of an elastomer, the pump is operational up to a temperature of 170 °C.

When conducting the pilot test in LLC LUKOIL Perm, there was a reduction in energy intensity for 1 m³ of the extracted commodity by 2.6 times compared to the previous operation of ESP.

Installations of RDCP, produced by JSC Novomet Perm, have been successfully operating at numerous fields in Russia and abroad. It is worth mentioning that the maximum runlife exceeded 1400 days. ●

Based on the materials of the 16th International scientific-practical conference "Mechanized oil production–2019"

COMPACTION OF THE OIL WELL NETWORK AS A WAY TO OPTIMIZE EXPENSES

SIGNIFICANT OIL RESERVES OF PJSC TATNEFT FIELDS ARE CONCENTRATED IN LOW-PRODUCTIVE DEPOSITS IN CARBONATE RESERVOIRS WHOSE OIL IS MAINLY CHARACTERIZED BY HIGH VISCOSITY. HOW DO THE COMPANY'S SPECIALISTS OPTIMIZE CAPITAL AND OPERATING EXPENSES WHEN SETTING UP DEPOSITS?

UDC 622.276

KEYWORDS: *field development, well network, carbonate reservoirs, low-productive deposits, high-viscosity oil.*

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In order to actively improve the competitiveness of the company Tatneft and the growth of its investment activity in 2018, the Board of Directors of PJSC Tatneft considered and adopted a new development strategy up until 2030. One of the projects approved by the General Director of PJSC Tatneft – Maganov N.U., implemented in the framework of the development strategy is: "Increase in the oil recovery rate due to the cost-effective production of compacted wells at the fields of PJSC Tatneft".

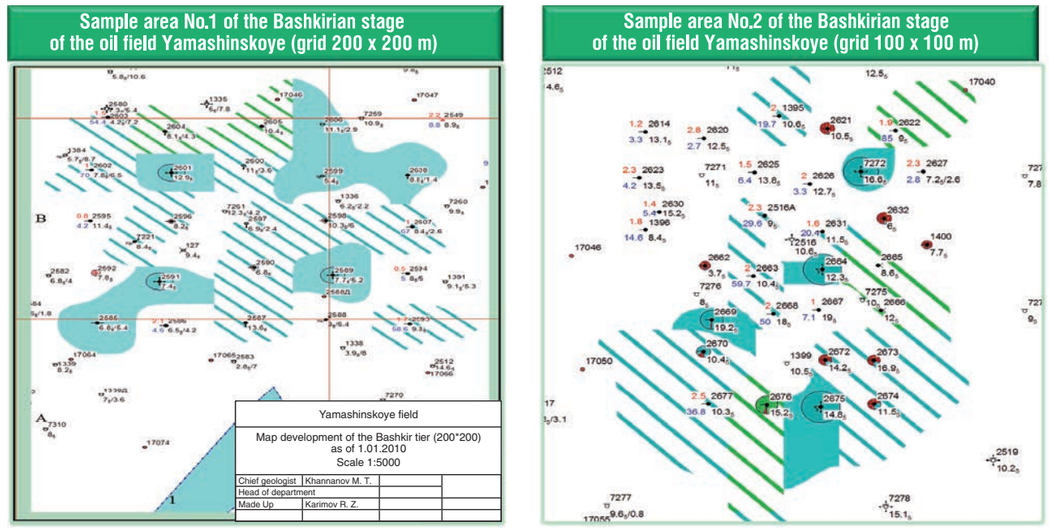
Currently, the significant oil reserves of PJSC TATNEFT fields are concentrated in complex, low-productive deposits in carbonate reservoirs where oil is mainly characterized by high viscosity. Current technological indicators of reservoir development are mainly explained by: low productivity of carbonate reservoirs, high geological non-uniformity of formations, high viscosity rate of oil, complex structure of the void pore space and the presence of cracks.

Back in the 1980s, the structural subdivision of PJSC TATNEFT – NGDU Yamashneft was focused on the experimental plots of the Yamashinskoye field, drilled on the experimental compacted network 200×200 and 100×100, and works were carried out to determine the production capacity of viscous oils in the Bashkir reservoirs, both in the natural mode of operation and in conditions of contour flooding. The results obtained allowed to determine the most effective modes of well operation and to select the best value of the density of the network for the operation of such areas.

Construction of wells based on compacted networks implies the drilling of small-diameter wells (SDW) and not traditional wells.

Replication of the construction of oil wells using a new technology with a production string diameter of 114 mm began in Tatneft back in 2006, while in 2016 an oil well was drilled with a diameter of 102 mm. Drilling small diameter wells in comparison with wells of traditional design allows to reduce costs by an average of 58%. However, it is not enough to just drill an oil well – it needs to be completed, i.e. an industrial flow of oil needs to be obtained, deep-well pumping equipment needs to be introduced, a pipeline system needs to be built and equipped with means of monitoring and measuring the flow rate of liquids. There have been new approaches and developments in these areas as well.

FIG. 1. Sample areas of carbonate reservoirs drilled by means of infill wells at the oil field Yamashinskoye of Tatneft PJSC



The key areas of cost optimization, in addition to drilling wells using the SDW technology, are as follows:

- *in terms of the layout of downhole pumping equipment:*

  the use of 16/13 mm rods instead of 22/19 strings, the use of 60 mm pump-compressor pipes instead of 73 mm pipes, the use of in-house, above-ground drives of lightweight sucker-rod pumping units: type PC-30 and PC-40, production Bugulma Mechanical Plant of PJSC TATNEFT, instead of PC-60 or beam pumping units.

- *in terms of infrastructure development and power supply:*

  the use of discharge pipes with a diameter of 57 mm instead of 89 mm, the use of one drainage well for every 3 oil wells, the use of pre-operated pipes for storm sewers, the use of smaller wire cross-sections AS-50 instead of AS-70, the use of a smaller wire cross-sections of power cable AVVG – 4×6 instead of 4×10, as well as complete transformer substation – 25kVA (pole-type), the use of group measurements for the flow rate of oil wells, the introduction of small-sized control stations for chain drives.

FIG. 2. Production well design

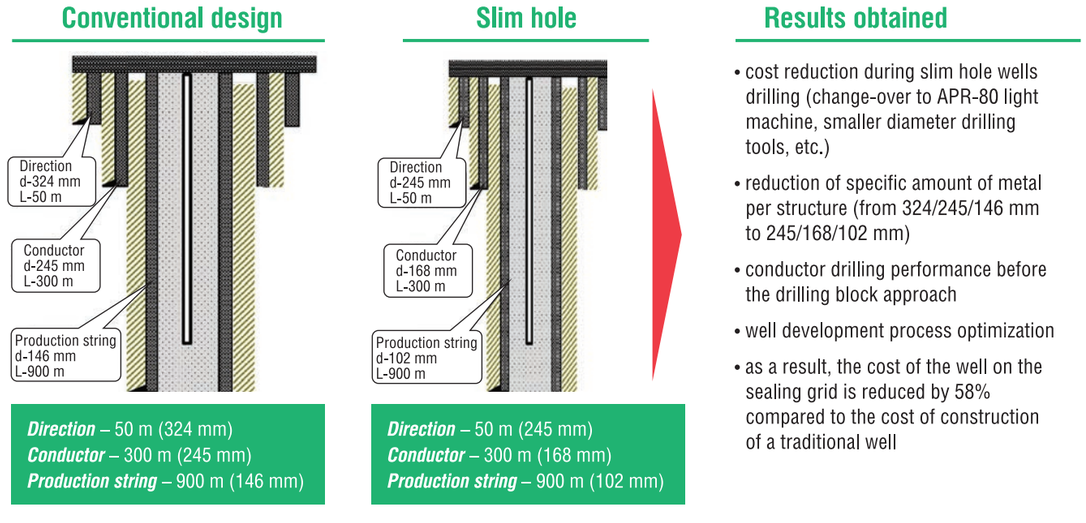


FIG. 3. Cost optimization at the top drive selection

Standard equipping of wells with PTs-60 and PShSNG-80 top drives on pressurized equipment

PTs-60-18-3-0.5/2.5
PShSNG-80-4.0

Equipping of wells with SMD PTs-30, PShSNG-55 top drives under the project of infill slim hole wells on pressurized equipment

PTs 30-10-3-0.5/2.5
PShSNG-55-4

Investment cost reduction per unit: chain drive by 39%
fluid drive by 61%

All these measures ultimately made it possible to obtain an investment efficiency 15% higher than the planned investment project within the payback period under conditions.

Furthermore, based on forecasts the implementation of this project over the next 15 years will increase the KIN factor (oil recoverability factor) at the fields by an average of 4–6%.

In total, over 750 wells were drilled at PJSC TATNEFT under this program, and the potential reserves for drilling amount to approximately 7,000 wells in 46 fields.

In conclusion, I would like to note that in 2019 NGDU Yamashneft will celebrate its 50th anniversary. Over the past years, the management team has solved many problems in the oil field development and production sector, as well as in the oil treatment sphere. I would like to congratulate the entire team of NGDU Yamashneft and the Director of NGDU Yamashneft Smykov V.V. on the occasion of our 50th anniversary and wish further success in production and stronger performance achievements.

FIG. 4. Oil well cluster No.17045 Yamashinskoye field – constructed as part of the project – WCD

«The future depends on what you do today»
(Mahatma Gandhi)

Based on the materials of the 16th International scientific-practical conference "Mechanized oil production – 2019"

TATNEFT 1969-2019 НГДУ «ЯМАШНЕФТЬ»

FROM INSIGHT TO WELL

How new technologies appear and where they come to

PRODUCTION AT MATURE FIELDS IS BECOMING MORE COMPLICATED, AND NEW EXPLORATION SUCCESSES LEAD PRODUCTION COMPANIES EITHER BEYOND THE POLAR CIRCLE OR TO THE CONTINENTAL SHELF, WHERE THEY INEVITABLY COME UP WITH A LACK OF TECHNOLOGY. THE ROUND TABLE “INNOVATION IN OIL PRODUCTION” HELD WITHIN THE FRAMEWORK OF THE CONFERENCE “MECHANIZED PRODUCTION” ADDRESSED THE THINGS TO BE DONE IN ORDER MODERN TECHNOLOGIES FOR OIL AND GAS PRODUCTION APPEAR IN OUR COUNTRY

UDC 330.322

Keywords: *technologies for oil production, investment, research and development, pilot industrial implementation, oil companies, pilot tests.*

World practice shows that the innovative development of the whole economy or any particular area of industry is almost impossible without the contribution of corporate venture funds to this process.

For Russia, this phenomenon is still relatively new, although as early as 2017 the President approved a list of instructions following the St. Petersburg International Economic Forum. It is assumed that the creation of corporate venture funds may become mandatory practice. Through them, it is planned to provide a breakthrough of this market from the current 14 billion rubles of investment per year to 410 billion (29 times) by 2030. This goal is written into the draft strategy for the development of the venture and direct investment market for the period up to 2025 and further up to 2030, the participant of the round table "Innovation in Oil Production", innovator Andrey Kuznetsov, says and asks: where do ideas for new venture innovation projects for implementation of this instruction and strategy come from, if funding increases by 29 times? It is obvious that mainly in large companies, because it is large companies that employ the main staff, and it is logical that major innovations appear there.

The birth of an idea

The basis for an innovative project in the oil and gas industry, in most cases, is an invention. Estimating the number of potential inventors, the speaker gives the following statistics: psychologists have found that about 2.5% of the adult population of the planet have the ability of the inventor and about 10–15% of the population internally intend to implement them. The rest do not invent themselves and, deep inside relate negatively to inventions of others. Assuming that 2 million people work in the oil and gas industry in Russia, the half of which is engaged in production activities (engineers, workers, programmers, drivers, builders, storekeepers, logisticians, dispatchers, communications operators, etc.), the speaker calculates that there are approximately 25 thousand potential inventors in the industry. And these creative personalities are distributed evenly throughout the industry, and in the industry – more or less evenly across enterprises. At enterprises engaged in research and development, the concentration is greater than elsewhere, but not much.

This 25-thousand army of potential inventors has a different way of thinking than ordinary people. When the inventor does something, he subconsciously thinks how to improve it. And sometimes this decision comes, and goes from the level of the subconscious to the level of consciousness. What is usually interpreted as the "insight".

But in most cases, the found innovative solution remains in the head of the inventor. An insignificant number of such employees dares to communicate the found solution to colleagues and the manager, document innovation or an invention, Andrey Kuznetsov states with regret. Why don't inventors do this?, the innovator continues and answers his question: just because life has taught them that the innovative proposal will be rejected. And if we consider how many managers the innovation must to “pass through” in order to be implemented, the probability percentage tends to zero.

It should be noted that exactly in mining companies innovations are most valuable and bring the greatest profit.

In order to encourage inventors to more often “bring out of the shadows” their innovative proposals, the speaker made an offer to create a parallel structure in large companies and state corporations that includes “Responsible persons for Invention Activities” reported directly to the Vice President for Innovations. The task of this responsible person will be to discern among the colleagues people “of his kind”, that is, those who are among 3% mentioned above, to establish creative communication with them and to convince them of the need to disclose their ideas. He should also help the inventor to conduct a patent search on the Internet, which immediately cuts off most of the inventions, as they were already invented earlier. And what else is important, he should tell about the rewards to be received for successful implementations. Both moral (the most important, in his opinion, for people of this psychotype), and financial. And also about the prospects of creating the so-called “spin-off”, if the invention does not keep with the corporation's technologies and about the possibility of returning to his/her or a similar position, if the “spin-off” fails.

Thanks to this organizational decision, the heads of ordinary production units of state-owned corporations and large businesses are exempt from functions that they cannot inherently do, i.e. from creating innovation. The decision relieve such managers from the necessity to imitate innovation activities that currently takes place in most cases to execute incoming orders from the top-down. Innovative technical and technological solutions will come to them later in the form of development already selected at the level of the senior management of the corporation and brought to the desired degree of maturity in its R& D divisions of the corporation, Andrey Kuznetsov summed up.

A way to well

Daniil Shaposhnikov from Phystech Ventures venture fund, who has been engaged in systematic investment in new oil and gas technology for four years, spoke about the difficulties of promoting new developments.

According to the speaker, the main reasons for a long pilot industrial implementation lie in the bureaucracy of oil companies. However, in recent years the situation has improved: oil and gas companies have begun to actively explore new technologies and now the main reason lies in the banal lack of investment money. In other words, oil and gas companies do not want to invest in start-ups. However, they give orders for R&D, and here is a situation where the emerging technology does not enter the market, but remains inside the company. Therefore, each company is forced to invent its own "bicycle".

In this regard, Start-ups are focused on the industry as a whole and for export. These companies are growing rapidly, working with the whole market, often seeking to go abroad. But the source of funding for such companies is extremely small, and there is only one venture capital fund.

Daniil Shaposhnikov noted another problem, which is the difficulty of getting a loan. For example, the speaker says, it is necessary to produce 10–20 machines of some equipment and launch mass sales. But for a venture fund, $ 3–5 million in one transaction is a big check, we don’t invest in one company more than $ 2 million, it’s also difficult to get a loan: the company has no assets, contracted revenue, a pledge base, a guarantor. As an option, you can attract money of a large oil company. This is the most expensive money. In this case, it would be more reasonable to take a loan, because it is impossible to promote technology to the global market without large-scale funding. According to our calculations, it takes two years to enter the market of only one country and deliver at least pilot product batches.

Today, the fund’s portfolio includes technologies for radial drilling, multilateral completion, vibro-impulse impact technologies and others, the speaker said and offered to have a look at the expertise of foreign colleagues, adding that most of the majors – BP, Total and others have their own corporate funds that invest in others venture funds promoting technology to market.

Venture Route

Another participant of the Round Table – Konstantin Nadenenko (Leader venture capital fund) announced the opposite view.

The key problem of the emergence of industry investment, in his opinion, is not lack of money. The problem is the lack of projects that can be submitted to external investors for judgement, which could be supported by such investors.

We are now launching a new fund together with a Chinese management company. The purpose of which is to invest in Russian technology projects entering the Chinese market. We have developed reliable models of this work and are confident that we can ensure the protection of intellectual property and the entry of companies into the huge emerging market.

The speaker said that the fund had already implemented twelve innovative projects and noted that many of them had been implemented brilliantly, many venture capital investments multiply the invested money dozens of times. This suggests that the mechanism is working, despite the difficulties, including international restrictions. Many tools have appeared that help developing projects in the right direction, including accelerators, thanks to which the average level of projects grows.

Accelerator Effect

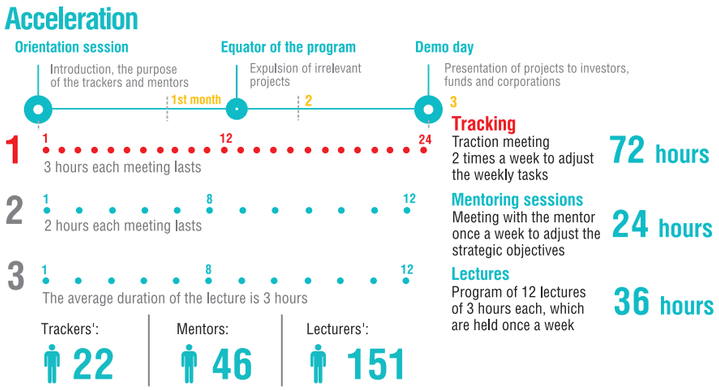
Director of the Center for Technology Transfer and Entrepreneurship of the Ural Federal University Nina Feodosiadi told about the work with innovative projects in industry and the role of accelerators in the promotion of new technologies.

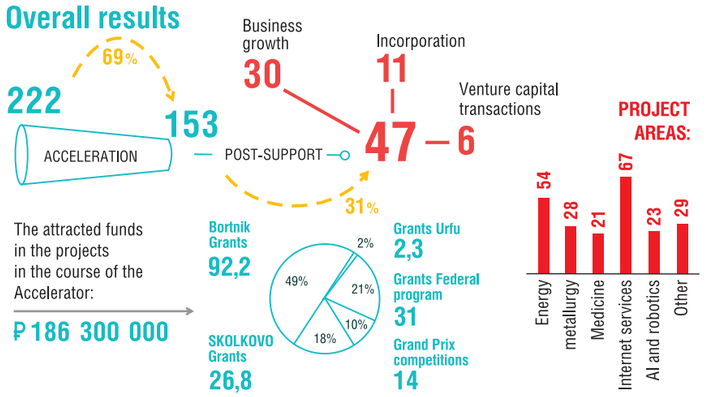
She said that when the Center had begun its activities based at the Ural Federal University, there had been no ready-to-use model for working with innovative projects, experts studied world practices and tested the work formats themselves.

From 2016, the Center began to make corporate accelerators as the operator of tracks of the Generations accelerator conducted by RVC JSC.

In 2018, we began to organize corporate accelerators for our partners themselves. Now we are doing a Corporate accelerator for Novomet-Perm JSC, and using the example of our entire experience and implementation of this particular project, we can identify the special aspects of working with innovative projects in the industrial sector, the Director of the Center says.

Firstly, it is very important that the Customer forms clear goals and objectives for attracting innovative projects into its orbit, to allocate resources for this in the work of people and management within the company, and the top officials of the company are involved in the process itself. To formulate the goals and objectives of the accelerator, we organize a preliminary session with the customer, where in fact we, together with the management, decompose the development strategy of the company itself into goals and objectives of the accelerator. We identify key resources that can be engaged in work with innovative projects. Completion of this stage is key for the successful following work on finding developments on topics of interest to the company. Next, we form the schedule and structure of the campaign to collect projects. And here we also have a number of know-hows: we always use analytical approaches to search for projects, use analytics tools of search channels, places for possible localization of interesting solutions, and virtually manually collect really new, potential and promising things.





Secondly, the most promising cooperation between the customer and the project team we have found is born when external projects are catalysts for the development of internal projects and innovative processes in the company. Using this principle, we build interaction within the entire accelerator team and moderate the process of interaction between external projects and the customer.

And the third important factor is that for us the activity in building the innovation process in companies is the core activity, therefore we understand and are able to achieve results in it. For any company, the core activity is its business, and the company's operating activities often do not allow paying due attention to building a full-fledged and efficient innovation process involving external projects.

In general, if we formulate the special aspects of corporate accelerators, it should be noted that, first, the corporate acceleration programs paradigm has changed.

A few years ago, accelerators were focused on the early stages of projects and the main tasks were testing hypotheses, examining the market, the educational component for projects, etc. Now corporations are focused on the search and selection of projects for cooperation under specific business goals and objectives. At the same time, despite the declaration of interest in projects at early stages (idea, R&D), the main focus is projects with a prototype and at more mature stages.

Secondly, the key task of corporate acceleration programs is to assemble a funnel of innovative projects and reduce the risk of partnership/investment. That is, the project turns from a “secret box” into a clear object: technology, team, intellectual property, potential for scaling, return on investment, etc. Pitch sessions, presentations, meetings with projects do not solve this problem effectively. This task is effectively solved by the individual project development trajectory, the availability of a supervisor and resource within the company, and the external moderation of the entire process using our methods.

Thirdly, acceleration programs are economically feasible for the customer, since they reduce the share of unsuccessful partnerships/investment.

Fourth, when designing and implementing an acceleration program, you cannot use standard patterns/approaches.

The speaker announced, among other features of acceleration programs, a preliminary session as the most important stage of the project, involvement of top management in the project, the need to use internal resources of the corporation to the maximum, as well as engaging mentors/supervisors from the Corporation. All this, according to Nina Feodosiadi, significantly increases the success of the acceleration program.

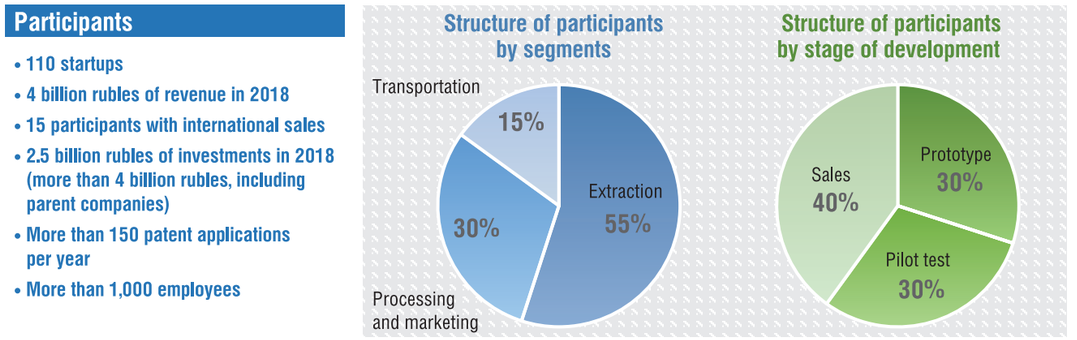
Successful projects from Skolkovo

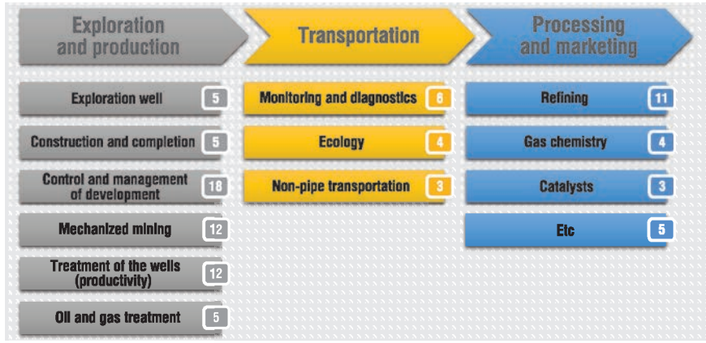
Of course, discussing innovation in the oil industry could not do without the Skolkovo Foundation. Oleg Pertsovsky spoke about the fund's portfolio and innovative project support tools in the oil and gas sector.

According to the speaker, Skolkovo is Russia's largest portfolio of successful technological start-ups. Currently, its portfolio includes 2,000 startups, with 30–40 new applications every week. During the last year alone, portfolio revenue was 70 billion rubles, Oleg Pertsovsky said.

Today, the Foundation is involved in the sectors such as energy, engineering, metallurgy, oil and gas, construction, housing services and utilities, transport, IT, fintech, telecom, biomed, agro-industry, aviation and space. More than 50 corporations have arranged their innovative divisions in Skolkovo, and more than 100 corporations have already implemented developments of Skolkovo members.

In the oil and gas sector, residents are developing projects related to the extraction, exploration, drilling, transportation, storage, processing and petrochemistry.





Talking about the most successful projects, the speaker gave an example of a number of companies. Thus, the main focus of ADLcompletions is development of domestic technologies of multilateral well completion for new wells and the D&C fund. In the course of the project implementation, 130 million rubles were raised in 2018 and 96 million rubles in 2017 with the support of Skolkovo Venchurs.

Another project, about which O. Pertsovsky told, is related to the production increase technology. We are talking about control devices that were developed by Wormholes and successfully passed pilot tests at Bashneft facilities with the support of Skolkovo.

Another example of the successful introduction of innovative technologies in the oil industry, which were discussed at the Round Table, is the intellectual injection & separation units of Aerogas. In May 2018, a comprehensive gas treatment unit was successfully commissioned at the Dobrinskoe field in the Volgograd Region. The customer of this project was the private gas producing company Gaznefteservis LLC of VolgaGas Group. The delivery of three internal pipe separator units to Yargeo in 2019 (NOVATEK), the delivery of an internal pipe separator for KazMunayGas to Kazakhstan was agreed, the Science and Engineering Board of Gazprom was held, a decision about pilot testing in Q2 2019 is taken. ●

Based on the materials of the 16th International scientific-practical conference "Mechanized oil production – 2019"

PRODUCTION MANAGEMENT

based on the neural network optimization of well operation modes at the BS_8 facility of the West-Malobalykskoye field

RECENT TRENDS IN THE PRACTICE OF OIL FIELD DEVELOPMENT ARE INCREASINGLY SHIFTING EMPHASIS TO THE PRINCIPLES OF ORGANIZATION AND MANAGEMENT OF WATERFLOODING SYSTEMS. IN THIS RESEARCH PAPER, THE AUTHORS PROVIDE EVIDENCE OF THE EFFECTIVENESS OF THE INTEGRATION OF DIGITAL TECHNOLOGIES FOR THE MANAGEMENT OF WATERFLOODING PROCESSES AND THE PLANNING OF TECHNOLOGICAL MODES OF OPERATION OF PRODUCTION WELLS AND INJECTION WELLS. THE AUTHORS ALSO INDICATE THE COURSE OF ACTION WHICH IS NEEDED IN ORDER TO DEVELOP THE PROSPECTS OF THE PRODUCTION MANAGEMENT TECHNOLOGY

UDC 681.5

KEYWORDS: *production management, digital technologies, flooding, technological modes, oil and gas extraction.*

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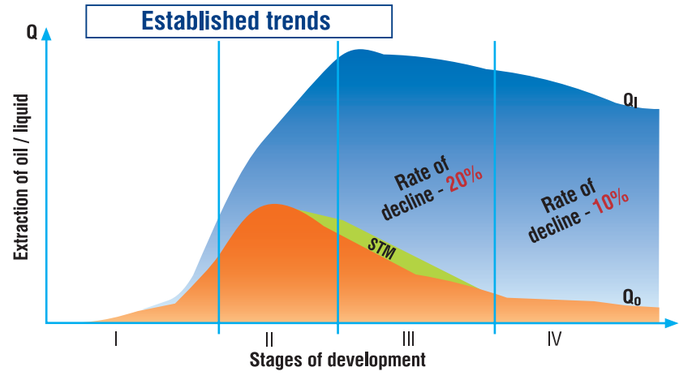
The fields that entered the III-IV stages of development are characterized by a fairly high rate of decline in oil production from the main well stock, reaching 20% (Fig. 1). Maintaining the level of production by drilling new sample points (side well, horizontal sidetrack) is associated with a high degree of risk and low profitability. The effectiveness of geological and technical actions at the main well stock is reduced in proportion to the degree of field development. The profitability of development is steadily decreased owing to an increase in operating costs and the cost of oil production, as a result of increasing water content. Under current conditions, the production management by way of regulating the modes of well operation is regarded as an effective way to reduce costs and increase profits [1].

The methodology of management decisions determines the entire further technological process and the final result obtained. The current paradigm in the management and production planning model assumes a start “from what has been achieved”: all works on the field are planned in terms of established trends. The decision-making process essentially involves subjective management, which is basically based on the intuition and personal professional experience of the company's specialists.

Over the past ten years, most companies in the oil sector, in an attempt to partially find a way to increase the profitability of production, have invested large amounts of money in the digitization of oil fields [2].

FIG. 1. Established trends in the development of mature fields



This large amount of investments has allowed to make a high-quality leap in the development of technical and information equipment for the fields. The oil field is actively equipped with various means of monitoring and measuring, receiving and transmitting data, creating information streams of tens and hundreds of gigabytes, which are received in real time.

In the conditions of the substantial increase of incoming information, it becomes unclear what the geotechnical engineer should do with the ever-increasing data flow, when even the available information is not fully in demand when managing field development and planning geological and technical actions.

A gap has been created between the possibilities offered by the new means of recording, controlling, transmitting and systematizing data, and the information that underlies the decision-making process. At the same time, the management and decision-making system remain unchanged, subjective, and, in the authors' opinion, anachronistic in respect to the opportunities provided by the level of development of tools for monitoring, transmitting and systematizing data.

The created groundwork, for the augmentation of the knowledge base in terms of processes occurring in the subsoil area, is not being implemented and, moreover, is not being transformed into additional oil production, and it follows from this that the enormous investments of oil companies in the digitization of oil fields are not paying off, and these investments constitute millions and billions of rubles of capital expenditures.

In this regard, the realization of the potential of the Digital field is possible in two ways:

1. *In the current model of management and planning "from what has been achieved":*

increasing the number of geological engineers to reduce the gap between the amount of incoming and utilized geological and field information. However, this option requires a significant increase in the payroll for production workers, in conditions of large capital investments for the development of the infrastructure of the Digital field.

2. *Transformation of the management model:*

Bridging the gap in the decision-making system between the incoming volume of information and the information currently used in order to manage development and the decision-making process by way of introducing digital decisions in the sphere of processing large amounts of data using machine-learning elements, which will pave the way for consolidating the entire amount of incoming information into the management decision format, available to the engineer developer and field geologist.

Transformation of the management model and the implementation of achievements in the BD and ML sphere into production

The accumulated history of development, which oil companies have today thanks to the introduction of monitoring and measurement systems, makes it possible to diagnose positive trends, associated with a decrease in production water content and an increase in the flow rates of wells that had been formed for years under the influence of geological, technological and human factors.

FIG. 2. Difficulties in solving the optimization problem

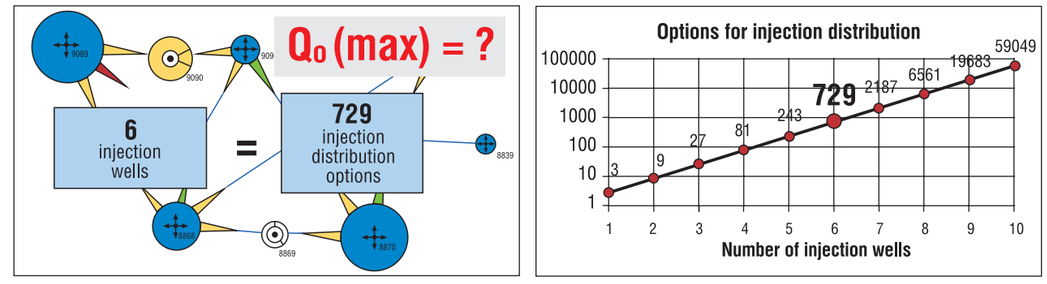
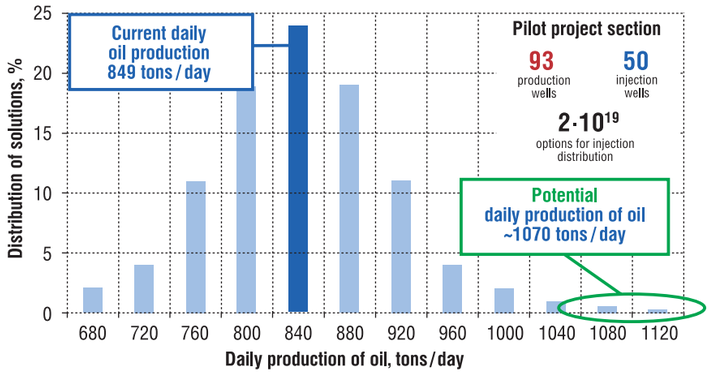


FIG. 3. Multivariance of the solution to the optimization problem



Replication of such trends, according to the authors, should be considered the main task of oil production in mature fields.

To describe the mutual interaction of wells in regard to the large amount of data, it is necessary to use machine-learning elements, which allows for the description of the relationship of each injection well with the dependent production well on a high level. The result of machine learning is a mathematical description of the relationship of the performance indicators (fluid flow rate, water content) of each production well and the performance indicators (injection capacity) of the neighboring injection wells, i.e. the so-called neural network or proxy model.

Accordingly, having a mathematical description of the relationships between production wells and injection wells in the form of a neural network, it becomes possible to solve the optimization problem in the following formulation: “How to distribute available resources in such a way so as to ensure the maximum development target (daily oil production)” [3]. At the same time, the number of possible options of injection capacity distribution, in which the sought solution can be found, even when no more than three changes (modes) are implemented in each well, increases exponentially and, for example, for an element comprising six injection wells, it reaches 729 possible options (Fig. 2). For an average field with the number of injection wells ranging from 30 to 50 – the number of possible injection distributions exceeds 1014 cases. Consequently, it is impossible to determine the best possible distribution pattern of injection wells, which will correspond to maximum oil production!

Consequently, the goal of integrating digital technologies into planning practice is to consistently shift the distribution of injection in the injection wells system to a range of the best optimal modes corresponding to the limited number of possibilities of injection well distribution in the right part of the distribution, which corresponds to maximum oil production [3].

Using the example of the West-Malobalykskoye field, the majority of the solutions for the optimization problem satisfy the current daily production of 849 tons per day (Fig. 3). In other words, even if we assign the operation modes of injection wells randomly, then the probability of obtaining the current production is quite high. However,

FIG. 4. Main diagram of the Production Management technology

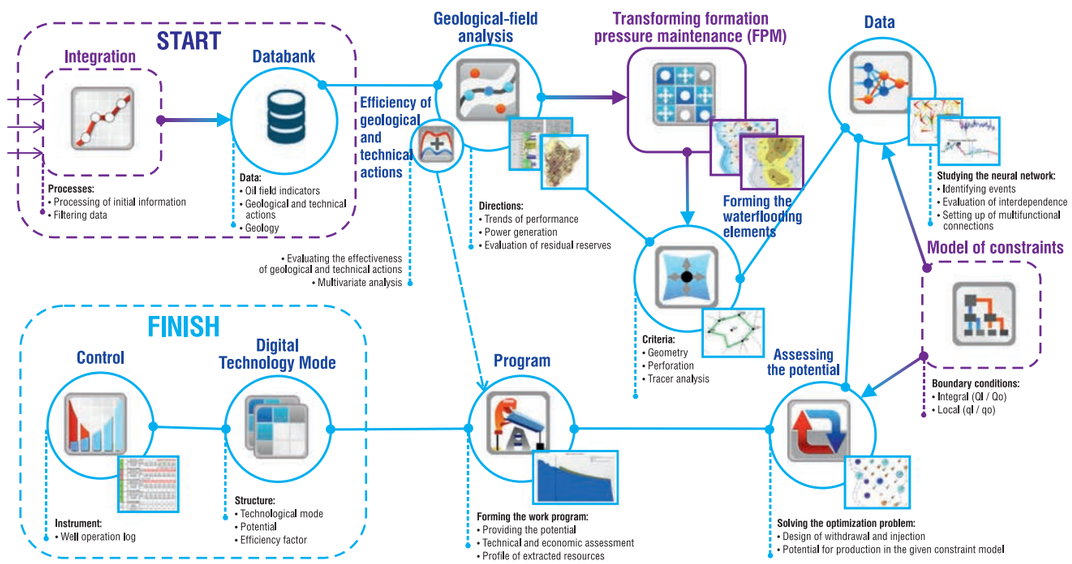
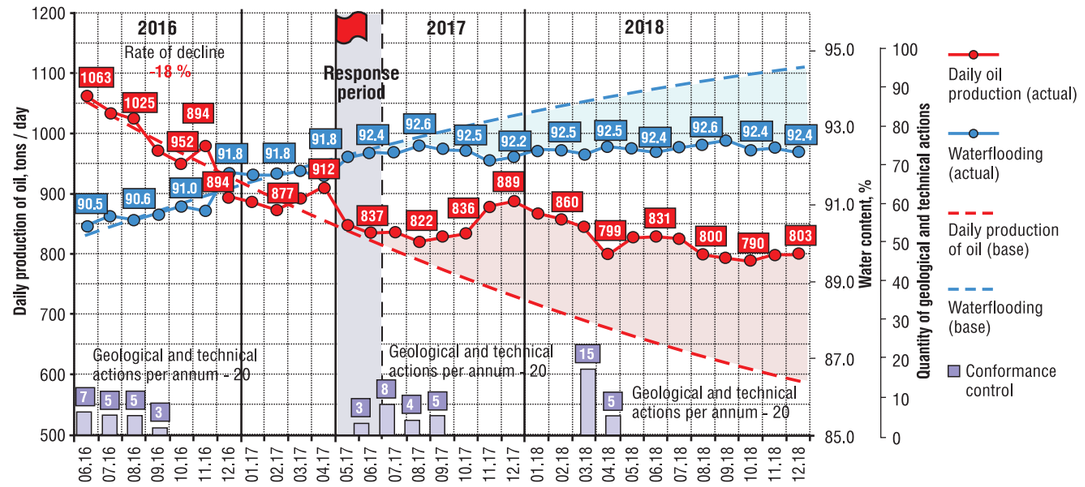


FIG. 5. Effectiveness of operations based on the Production Management technology



we are also interested in the area of rare decisions that are virtually impossible to get by chance: the potential of such decisions on daily oil production is ~ 1070 tons / day, which is 25% higher than current development figures.

Therefore, we proceed to the transformation of the model for production management with the aim of attaining the implementation of the **development system potential** [1]. The solution to the optimization problem is reflected in the technological mode of wells. In contrast to the classical form of representation of the technological mode (separately for injection wells and production wells), we present a new form for displaying the best optimal and recommended modes, compiled in terms of the analysis of elements (production wells and the surrounding injection wells). Thus, we propose to use the technology of converting large data arrays into the format of management decisions, which will be accessible to the field geologist.

Implemented strategy of technology introduction

The practice of implementing technologies for management and production planning "from the potential" includes the following key components:

Stage 1. *Studying the object (site)*

Works on the introduction of technologies for management and production planning "from the potential" start with the stage of studying the object, and involve the following:

- Identifying major trends in hydrocarbon production and factors constraining production, issuing recommendations aimed at preventing the loss of recoverable reserves.
- Forming the technological model of constraints: integral levels of injection and fluid production, geological and technical characteristics of wells, and the system of arrangement.
- Creating and configuring the proxy model of well influence in order to generate processes in the water injection system, aimed at reducing the water content in production wells.
- Assessing the potential of the implemented development system. The creation of a roadmap for work: the element-oriented purpose of the digital technological mode, according to the potential for the extraction of waterflooding elements.

The main diagram of the sequence of operations when introducing the Production Management technology is shown in Figure 4.

Stage 2. *Pilot works on a section of the field*

At the stage of pilot industrial works, introduction of the Production Management technology is carried out into the services of the oil company. This involves the continuous interaction of the institute and field specialists as part of the multidisciplinary team.

The stage of pilot works is carried out on a high level and highlights the main duties and competencies of the institute’s specialists.

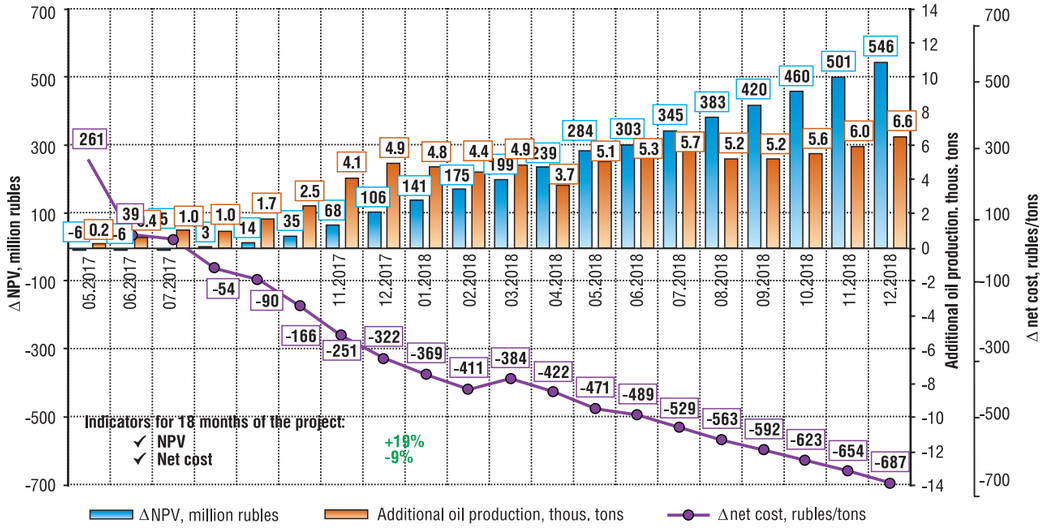
Stage 3. *Industrial implementation on the field*

Project office specialists receive the main competences for the effective management of production on the basis of an integrated work planning system, reorienting the competences of the institute in the project support sphere.

Results achieved

During one and a half years of implementation of the Production Management project in cooperation with KanBaikal LLC, on the BC8 site of the West Malobalykskoye field, a significant reduction in the average annual rates of decline in oil production from **18%** to **4%** was achieved (Fig. 5).

FIG. 6. Economic efficiency of operations based on the Production Management technology

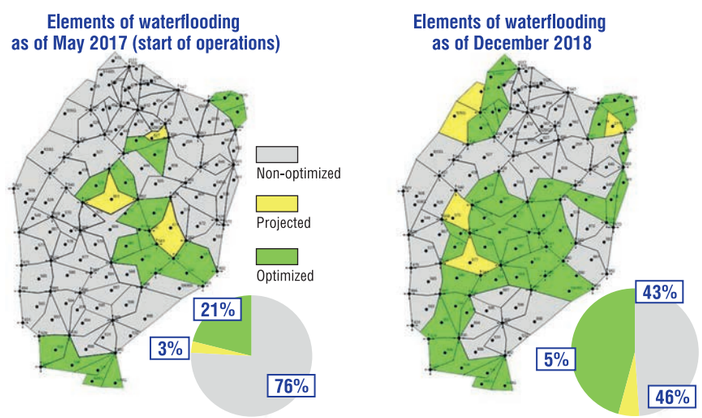


During the period of operations from 1 May 2017 to 1 January 2019, oil production exceeded baseline indicators by 18%, in absolute figures this constitutes 78.5 thousand tons of additional oil production.

The growth in oil production relative to baseline indicators is characterized by a period of stable fluid production, which suggests that the effect of the introduction of the Production Management technology is not due to the intensification of oil production, but only to the rational distribution of injections over the specified area. It should be noted that the number of geological and technical actions conducted during the project implementation period does not exceed the number of geological and technical actions carried out during the same period of development prior to the introduction of the technology (Fig. 5).

The growth in oil production is accompanied by a decrease in the water content of wells, which is stabilized at 92.4%. The reduction in the share of simultaneously produced water allowed, within an eighteen-month period, to reduce the cost of oil production by 9%. Moreover, the economic efficiency amounted to 546.5 million rubles in total or 3.8 million rubles per unit in terms of well stock (Fig. 6).

FIG. 7. Optimization of the waterflooding system



Preliminary results of the implementation of digital solutions into the practice of production management in the West-Malobalykskoye field indicate the achievement of the stated goals and confirm their effectiveness.

Performance indicators

Control of the efficiency of the process is monitored using unique digital efficiency indicators of the planning and management model [4].

Optimization

One of such indicators is the optimization indicator, which characterizes the degree of deviation from current injection modes from the optimized ones.

The waterflooding element is a group of wells where one is the production well, and the adjacent one is the injection well.

There are three levels of optimization of the waterflooding element – optimized, projected and non-optimized:

1) optimized – the current injection into the element has reached the best optimal level, the potential for oil production intensification has been achieved;
2) projected – the current injection into the element has reached the best value, the potential for oil production intensification has been created;
3) non-optimized – the current injection into the element has not reached the optimal level;

Over the course of some time, in December 2018, the optimization of the waterflooding system (the ratio of optimized and projected elements to the total number of waterflooding elements) of the BS_8 site reached 48% (Fig. 7), which had a positive effect on oil production trends.

However, the comparison of two discrete points of general optimization at the time of commencement of works and at the end of 2018 does not fully reflect the dependence of daily oil production on the level of optimization. The effectiveness of implementing the Management Production technology is characterized by the number of optimized elements, which, based on practice (Fig. 8), is described by the direct link between the level of optimization and the indicator of daily oil production.

The graph clearly shows that as soon as the optimization of the

FIG. 8. Comparison of daily oil production and optimization of waterflooding elements

Parameters	May 2017	June 2017	July 2017	Aug 2017	Sep 2017	Oct 2017	Nov 2017	Dec 2017	Jan 2018	Feb 2018	Mar 2018	April 2018	May 2018	June 2018	July 2018	Aug 2018	Sep 2018	Oct 2018	Nov 2018	Dec 2018
Daily production of oil, tons / day	849	837	839	822	830	836	880	889	868	860	847	799	829	831	826	800	794	790	800	803
Δ daily oil production	–	-12	+2	-17	+8	+6	+44	+9	-21	-8	-13	-43	+30	+2	-5	-26	-6	-4	+10	+3
Evolution of optimization, %	26	21	32	29	40	34	36	41	38	32	26	31	34	37	34	31	19	20	27	26
Δ of evolution of optimization	–	-5	+11	-3	+11	-6	+2	-5	-3	-6	-6	+5	+3	+3	-3	-2	-12	+1	+7	-1

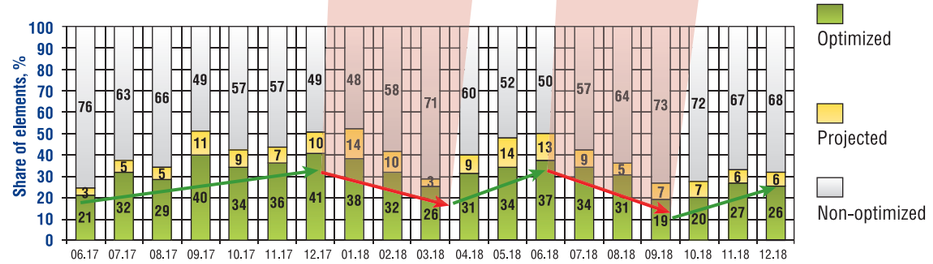


FIG. 9. Distribution of waterflooding elements according to the criterion of stability of optimal injection modes

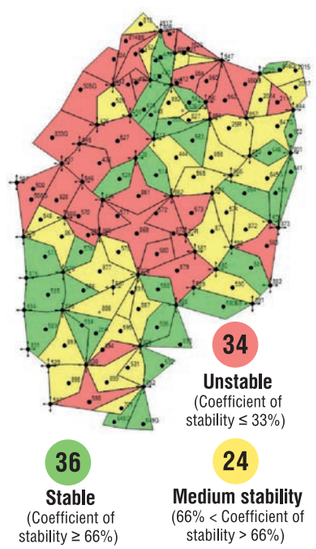


FIG. 10. Comparison of the average rate of decline of stable and unstable waterflooding elements

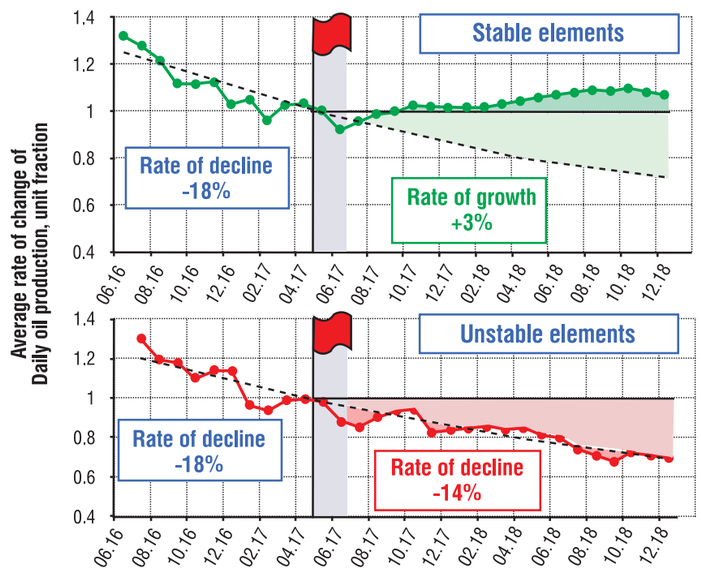
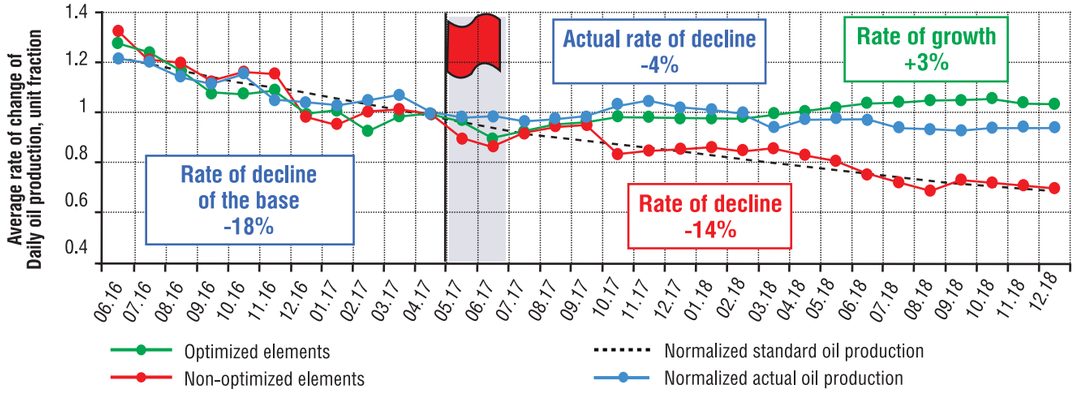


FIG. 11. Dimensionless dynamics of technological indicators



elements of waterflooding begins to decline, then the daily oil production shows similar dynamics. Consequently, in addition to the absolute effect of the introduction of the Production Management technology in the form of additional oil production, the graph illustrates the nature of this effect.

Stability of injection modes

In addition to the optimization of injection modes, an important criterion for the efficiency of operations is the stability of the optimization of waterflooding elements. The stability coefficient of the optimal modes characterizes the share of calendar time per annum when the waterflooding element was in the optimal category or the projected category (Fig. 9).

In terms of the dynamics of daily oil production by well groups of stable and unstable waterflooding elements, there is a striking difference in the development indicators (Fig. 10).

The dynamics of daily oil production for a group of waterflooding elements with a low coefficient of stability is characterized by a decrease in daily oil production in both 2017 and 2018, while the rate of decline of production in average annual terms is about 14%, which corresponds to the baseline rates of decline in oil production set out for 2018.

On the other hand, in terms of group waterflooding elements with a high stability coefficient (Kst > 66%), an increase in daily oil production in 2017–2018 is noted, while the rate of growth in average annual indicators is about 3%.

It should also be mentioned that both groups of stable and unstable waterflooding elements at the start of operations of the Production Management project show similar rates of decline (Fig. 11), which once again confirms the effectiveness of the presented technology.

Directions for further project development

Ambitious plans for the development of the project are outlined for 2019. Development is planned in three main areas:

- Software integration, passing on of competencies as part of the Production Management project of the BS_8 site of the West Malobalykskoye field to the specialists of KanBaikal LLC;
- Launch of a pilot project for installation of equipment for remote control of injection modes on the premises of two cluster platforms of the BS_8 site – “Robotic site”;
- Technology scaling within the company.

Conclusion

1. The proven efficiency of integrating digital technologies for managing waterflooding processes and planning the technological modes of operation of production wells and injection wells is expressed by an increase in oil production relative to the baseline indicators by 18% and a reduction of operating costs up to 9%.
2. For the successful implementation of the project, close cooperation with the specialists of the relevant services of the company is needed in order to increase showings of digital performance indicators, such as stability and optimization of injection modes, the high indications of which are necessary for increased oil production.
3. Prospects for the development of the Production Management technology are associated with the integration of management services, the robotization of processes for regulating the operating modes of injection wells, and the scaling of technology within the enterprise. ●

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POLAND BUYS RECORD AMOUNT OF RUSSIAN COAL

DZIENNIK GAZETA PRAWNA

Almost 80% of Poland’s energy production is generated from coal and the country is constantly increasing the volume of purchases of this raw material from Russia.

The Russians say that the markets of Western countries, which plan to phase out reliance on fossil fuels in the long term, are not included in their list of priorities. The exception is Poland.

Vladimir Putin set the task to increase coal exports by 50%. Exports will mainly go to China, India, Turkey and the countries of South-East Asia. The Russian authorities have stated that they will coordinate their steps with Russian Railways and seaports: in regard to railway transportation, primarily on the Trans-Siberian and Baikal-Amur rail networks, there are still bottleneck sections through which it is physically impossible to transport a large amount of raw materials. In order to change the situation, it will take 1.5 trillion rubles to make changes and improve the situation. It is still unclear whether the needed financing will be available, and, as a result, whether Russia will succeed in increasing the volume of supplies to Asia.

OIL PRICES NOW DEPEND ON RUSSIA AND SAUDI ARABIA

A meeting of OPEC countries including Russia (OPEC-Plus group) was held in Jeddah during which discussions were held on the oil production strategy until the end of 2019. Countries are concerned about the possibility of a decrease in supply on the oil market. However, opinions are divided: Saudi Arabia insists on continuing to reduce oil production, while Russia suggests revising the restrictions.

Russia and Saudi Arabia are considering two scenarios where it would be possible to increase oil production. The first scenario envisages a change in the supply limit of 1.2 million bpd to 900 thousand bpd. The second one implies a reduction in production from a number of countries on a greater value than was stipulated by the agreement, which makes it possible to increase production by 800 thousand barrels per day.

Experts conclude that OPEC-Plus countries are open to the possibility of increased production for the remaining half of 2019, however, there is a tendency to act with caution as there are concerns about a possible new fall in prices.

DRUZHBA PIPELINE IS NOT AS FRIENDLY AS IT SEEMS

RZECZPOSPOLITA

The Polish pipeline operator has promised to resume oil supplies via the Druzhba pipeline only after receiving compensation and negotiations have been scheduled for June 3. The Poles claim that Russia is blaming them for prolonging the dispute, while the Russians argue that Poland has overstated the volume of substandard crude oil by way of diluting the contaminated oil in order to receive more money.

D. Kozak said that “there are controversial issues related to the way the crude has been stored as only one volume had been contaminated, and today we are told that the quantity is much higher”. He added that the Polish side, without informing the Russian side, diluted the dirty oil with clean oil.

The pipeline operating company PERN issued a statement where it was stressed that if the Russian side fulfills its commitments, "the Polish transportation route will be completely clean within five months".

These complaints have been set out only by the Polish side. Other operators (Belorussian, Ukrainian and Slovak) have accepted Russian terms without any resistance and have opened the pipeline valves. ●

ASSESSING OF DIOXIDE CARBON EMISSION AS GREENHOUSE GAS IN TUNDRA ECOSYSTEMS

THIS PAPER IS DEVOTED TO ASSESSING THE *IN SITU* DIOXIDE CARBON EMISSION AS GREENHOUSE GAS IN TUNDRA ECOSYSTEMS USING THE OPEN-TOP CHAMBERS WITH EXPERIMENTAL ELEVATED TEMPERATURE AND THE CONTROL PLOTS. THE RATE OF CO_2 EMISSION IS GREATLY INCREASED DUE TO EXPERIMENTALLY CAUSED WARMING AND LEADS TO A NET LOSS OF CARBON FROM THE "SOIL-PLANT" SYSTEM AT ELEVATED TEMPERATURES COMPARED WITH NORMAL TEMPERATURES. THE INCREASE OF PLANT BIOMASS TO WARMING WAS LARGELY DUE TO THE RESPONSE OF LICHENS AS THE DOMINANT COMPONENT OF THE DWARF SHRUB-LICHEN TUNDRA

UDC 502.7

Keywords: *dioxide carbon emission, open-top chambers, control plots, tundra ecosystems, in situ monitoring.*

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Greenhouse gases are gaseous substances that create a greenhouse effect above the Earth by absorbing and retaining excess heat emitted from the earth's surface in the atmosphere. The greenhouse gases making a main contribution to the total greenhouse effect are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4) and ozone (O_3) [1]. Among them CO_2 present special interest as most closely connected with functioning of the gas industry objects and terrestrial ecosystems and its emission into the atmosphere occur at:

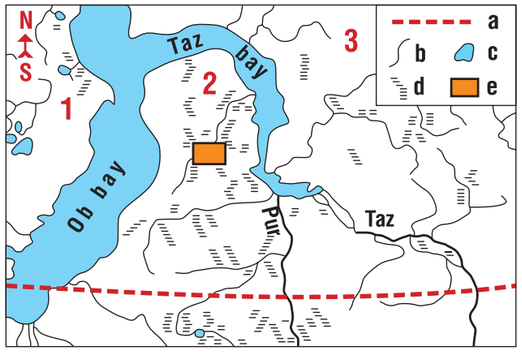
1) burning of natural gas at different technological processes: working of compressors, gas pumping units and gas turbines etc.;
2) respiration of soil microorganisms and plant roots, whose contribution to CO_2 emission is important for modeling and estimating the carbon balance in tundra ecosystems [2].

Meanwhile, it was of interest to estimate CO_2 emission in tundra ecosystems, in the conditions of current strengthening of climate continentality associated with large annual fluctuations in air temperature, i.e. warm summers and very cold winters, in particular in the polar latitudes [3]. This is extremely important, as the increase in the rate of CO_2 emission and the associated increase in the biomass of plants in warm summer conditions in the polar latitudes should have a positive impact on the process of the rapid recovery of disturbed tundra soils devoid of fertile layer at functioning of the gas industry objects that are produced by innovative biogeochemical technologies [3]. With regard to CO_2 emission from the gas industry, this process is virtually independent of the phenomenon of climate continentality strengthening.

Considering global climate change and its impact on the Arctic ecosystems, it has been hypothesized that warm summers will lead to significant vegetation change: to reduce the biomass of mosses [4] and a significant increase in the proliferation of shrubs [5]. In addition, warming can cause changes in the intensity cryoturbation processes, giving, thus, the change in the result of transformation processes in the Arctic soils [6]. Taken together, these changes in the environment can significantly affect the structure and function of bumpy tundra, but the magnitude and sequence of such changes is still unclear, since our knowledge of the patchiness of this complex system is very limited. Because the Arctic ecosystems store large stocks of soil carbon [7], changes in biogeochemical cycles can also be very important when considering a reverse correlation with warming. Detailed studies of the carbon and nitrogen of the background soils of tundra ecosystems and its heterogeneity in space are the necessary basis to study the effects of elevated temperatures on biogeochemical cycles of carbon and nitrogen [8].

Earlier field monitoring data in gas industry impacted zones of the Taz peninsula (the Yamalo-Nenets autonomous okrug, 67°15' N, 74°40' E) did not show any anthropogenic influence on CO_2 and CH_4 emissions (Fig. 1) [8–10].

FIG. 1. Map-scheme of the research territory



1 – The Yamal Peninsula; 2 – The Taz Peninsula (68°09' N, 76°02' E); 3 – The Gydan Peninsula; *a* – The North Polar Circle, *b* – rivers, *c* – lakes, *d* – swamps, *e* – localization place of the control plots and open-top chambers (OTCs)

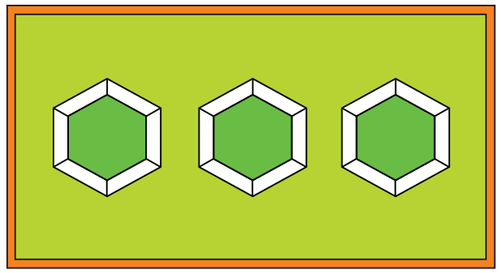
With warming, it is assumed that the decomposition of soil organic matter will be accelerated and therefore will increase the release of carbon from soils to the atmosphere [11]. Enriched CO_2 atmosphere may increase warming due to feedback effects, despite an equivalent increase of production net primary production, offsetting the accumulation of CO_2. However, it remains unclear what amount of carbon can potentially be released from soil due to warming. Furthermore, in the north of West Siberia at regional scale, the opposite process of climate cooling is observing [12] and this should be taken into account as well.

In connection with the above, the main objective of this work was the *in situ* assessment of CO_2 emission and associated plant biomass in warm summers in the polar latitudes for a clear view of the prospects of recovery of disturbed tundra soils at functioning of the gas industry objects with help of the innovative biogeochemical technologies [3].

Research methods

The *in situ* study of the effect of elevated temperatures on the processes of carbon and nitrogen cycles and productivity of tundra plants was performed using the open-top chambers (OTCs) according to standards of the International Tundra Experiment (ITEX) (Fig. 2) [13, 14]. The OTCs are transparent plastic truncated hexagonal pyramids that were installed in tundra ecosystems on the Taz Peninsula approximately 5 km from the Yamburg gas condensate field, i.e. in the background area. It is known that in the OTCs average temperature of surface air is increased by an average of 2–3°C in comparison with the adjacent territory, allowing in natural field conditions to investigate the

FIG. 2. Schematic image of the open-top chambers, OTCs (in the form of truncated hexagonal pyramids) on plot (at top view)



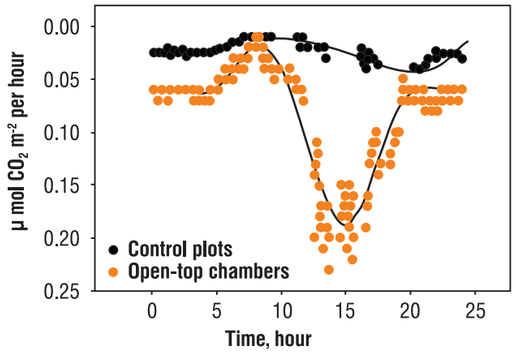
effects of elevated temperatures. For the study of air samples inside the OTCs and in the control area, i.e. outside the OTCs, according to the appropriate technology, were taken in hermetically sealed containers, in which the CO_2 content was analyzed than the *in vitro* conditions by gas chromatography method. Besides, in samples of the soils and plants determined the content of carbon and nitrogen by method of the dry burning in oxygen current.

Research results

The dynamics of the rate of CO_2 emission from the control plots and the OTCs were studied during the day. In the presented results of the CO_2 emission (data on average for 15 days) were due the respiration of soil microorganisms and plant roots, less absorption of CO_2 during photosynthesis (Fig. 3).

In general, the rate of CO_2 emission is directly dependent on temperature due to incoming solar radiation. However, in case of the control plots, the dynamics of CO_2 emission was expressed quite mild during the day (varying within a narrow range from 0.02 to 0.04 μm/m² per hour), the OTCs emission rates were changed on average from 0.02 to 0.19 μm/m² per hour. The maximum emission was observed at around 3 p.m. By 8 p.m., the rate of emission is

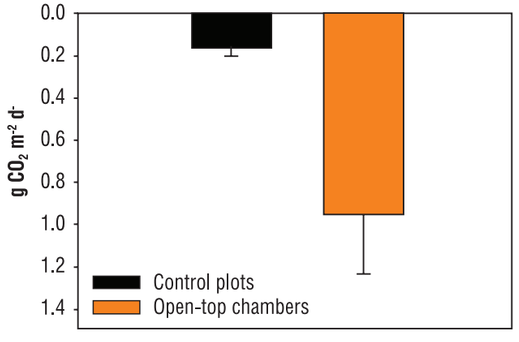
FIG. 3. Dynamics of the rate of CO_2 emission from the control plots and open-top chambers, OTCs during the day (average data for 15 days)



significantly reduced to 0.06–0.07 μm/m² per hour, but still remained higher compared to control. In the evening and night hours (until 3 a.m.) the rate of CO_2 emission remained approximately at the same level. From 3 a.m. to 9 a.m. there was a gradual decrease in the rate of CO_2 emission to values typical for the control plots. After that, there was a sharp increase in the rate of emission with a maximum at 3 p.m.

Calculated over the observation period the total CO_2 emission of allows to making a preliminary conclusion: despite a small increase in average temperature (by 2–3°C), rate of CO_2 emission in an average day increased 6-fold compared to control, reaching a value of almost 1 g CO_2/m²/day (Fig. 4).

FIG. 4. Total for the day CO_2 emission from the control plots and open-top chambers, OTCs (average data for 15 days in 3 field replicates)

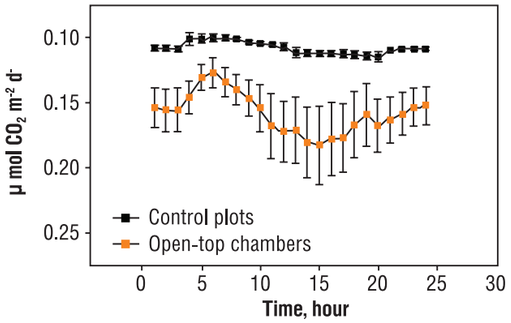


The carbon content in the horizon of accumulation of soil organic matter significantly decreased by 4.7% in the OTCs, compared with the control, while the nitrogen content increased and overall warming effect on the availability of soil nitrogen was significant.

The trend of the CO_2 flux during the day was similar for the OTCs and control plots (Fig. 5).

Net CO_2 balance in the ecosystem, i.e. the difference between its sink and emission was positive early in the

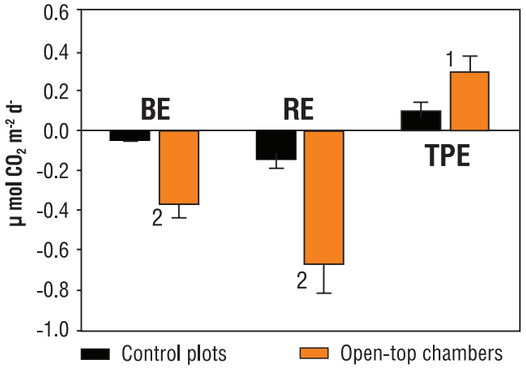
FIG. 5. Changing CO_2 balance in ecosystem during the day after 2 years of the experimental warming



morning along with the beginning of photosynthesis, which means that the sink of CO_2 into "soil-plants" system.

During the day, ecosystem respiration dominated by photosynthesis showing negative values of CO_2 exchange rate. Negative values on the graph respectively represent the net emission of CO_2 into the atmosphere. At the control plots the daily CO_2 balance however was close to zero, i.e. the rate of photosynthesis and respiration were balanced in the study period. The average values of net CO_2 balance at the maximum illumination were significantly lower in the OTCs than in the control, which means increased CO_2 emission to the atmosphere from these OTCs (Fig. 6). Total carbon losses from "soil-plant" system were 8 times higher in the OTCs compared with the control plots. Accordingly, the respiration of the ecosystem in the OTCs increased by 5 times, and the rate of photosynthesis – 3 times.

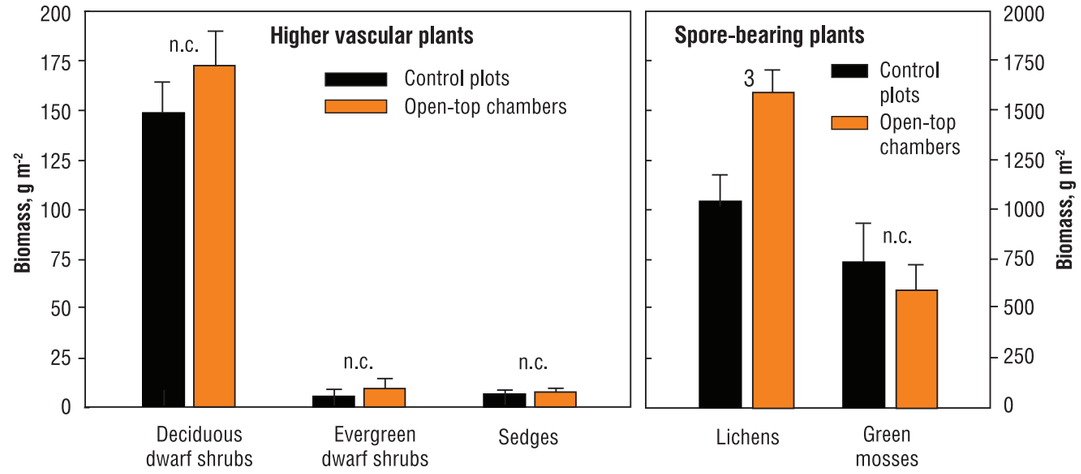
FIG. 6. Effect of experimental warming on the CO_2 balance of the ecosystem (BE) at maximum illumination, total "respiration of the ecosystem" (RE) and total photosynthesis of the ecosystem (TPE) in the dwarf shrub-lichen tundra (1 – $p < 0.05$, 2 – $p < 0.01$)



As already noted, the aboveground plant biomass significantly increased after two years of experimental warming.

However, related to increased photosynthetic fixation of carbon is not compensated for the much greater

FIG. 7. Effect of experimental warming on aboveground biomass of plants of the dwarf shrub-lichen tundra (3 – $p < 0.005$; n.c. – not certain)



losses of CO_2 from ecosystems due to experimental warming that may be caused by the increased respiration to both respiration of soil microorganisms and plant roots. The carbon/nitrogen ratio in the plant biomass was unchanged and therefore, plant growth was not limited by nitrogen at elevated temperatures.

The impact of experimental warming on the biomass of individual species is shown in Fig. 7.

Aboveground plant biomass significantly increased after two years of experimental warming, mainly due to the lichens that stood out for their strong response to temperature increases and accounted for 95% of the total aboveground plant biomass. Deciduous dwarf shrubs (*Betula nana, Vaccinium uligunosum, Salix glauca*), an evergreen dwarf shrubs (*V. vitis idaea, Ledum decumbens*), sedges and mosses did not show significant changes in biomass with warming. However, the leaf surface of *Betula nana* significantly increased by 63% in the OTCs compared to control plots. The total content of carbon and nitrogen in aboveground plant biomass was also significantly higher in the OTCs compared with the control plots.

Conclusion

Thus, the increase of plant biomass for the experimental warming is largely due to the response of lichens, and this is the dominant plant component of the dwarf shrub-lichen tundra. The rate of CO_2 emission is greatly increased due to warming and leads to a net loss of carbon from the "soil-plant" system at elevated temperatures compared with normal temperatures. This confirms the hypothesis that, as a result of warming, the net carbon balance of the Arctic ecosystems (at least in the short term) could change from a net sink of carbon to its clean emission. The responses of individual processes to the warming likely depend on the type of the system under investigation, which requires experimentation with the manipulation of temperature in a variety of plant communities and soil types.

With regard to the observed increase in the rate of CO_2 emission and the associated increase in plant biomass under the conditions of the 2–3°C increase in summer temperature modeled by the OTCs, this is of practical importance for the accelerated recovery of disturbed tundra soils at functioning of the gas industry objects using innovative biogeochemical technologies [3].

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2.1.1 Geological exploration

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CABLE-TOOL	**168**
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WITH CLEANING	**215.9**
WITH BLOWING	**250**
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INSERT BITS

1. Drilling equipment and instruments

1.1.1.12 Drilling tools

1.1.1.12.1 Bore bits

Insert bit is crumble and crumble-sliding instrument, applied for rock breaking. The main operating unit is the roller hit features the cone-element, made from steel. The cutting structure of the roller hit is lobes of different length or dowels, made from tungsten carbide. This cemented carbide is used for breaking different geological material as soft, as sufficiently hard.

Insert bit is the system the rotation around of its axis is possible due to the rotation of the housing. In the result of operating the mechanism, the breaking of the geological material in place with the lobes in a contact with them is made. Rolling hits have the special design: the presence a lot of lobes, placed in a special way. They are positioned in a way that the geological material is broken on the whole girth of the place.

Insert hits have some important systems: greasing and cleaning. The equipment may be manufactured with the side or central cleaning system. In the first variant, the fluid from the holes is directed on the roller hit. At the presence the special strips on the holes, the system is called water jet system.

The usage of the insert hits

For drilling gas/oil wells the insert hits equipped with cone roller hits are applied.

The instrument is widely used for drilling the exploration, gas and oil wells. The y also applied in mining and building. The hits have a lot of advantages. They are:

- Sufficient contact surface with the place.
- Long length of the cutting edge that increases the efficiency when operating with the instruments.
- Low level of lobes crumbling.
- Short roll torque, so the danger of the insert hit jamming is minimum. ●

"The issues of efficiency, reliability, security of energy supply, quality and cost of electricity for consumers are closely connected to the growth rate of the Russian economy"

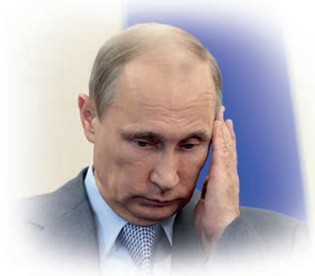
P. Zavalny

"We should try to be competitive as we all exist in the global competitive struggle, and every year the situation becomes more and more difficult"

Yu. Shafranik

"Russia needs to maximize its main competitive advantage – the presence of fairly inexpensive hydrocarbon reserves"

P. Sorokin



"We should think about how we influence the global energy market"

V. Putin

"Until economic growth is accelerated, the issue of actual earnings will always be a problem"

A. Kudrin

"One ruble invested in Arctic projects attracts a further 15 rubles"

D. Kobylkin

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