Please fill in the name of the event you are preparing this manuscript for.	2022 International Petroleum Technology Conference
Please fill in your 5-digit IPTC manuscript number.	IPTC-22042-MS
Please fill in your manuscript title.	Directional Radial Drilling Increases Reservoir Coverage With Precise Wellbore Placement Resulting In A Significant Production Increase From A Thin Reservoir

Please fill in your author name(s) and company affiliation.

Given Name	Surname	Company
Ayrat	Bashirov	LLC Perfobore
Ilya	Galas	LLC Perfobore
Marat	Nazyrov	LLC Perfobore
Dmitry	Kuznetsov	LLC LUKOIL-Komi
Azamat	Akkuzhin	LLC LUKOIL-Komi

Introduction

The analyzed field is the Osvanyurskoye one. It was discovered in 2007. The field is located in the north-east of the European part of the Russian Federation, 2 km from Usinsk in the Komi Republic. The field is a part of the Timano-Pechora oil and gas province and it is a mature field (fig. 1). The objective was a 2.5m thick layer of the Serpukhov horizon.

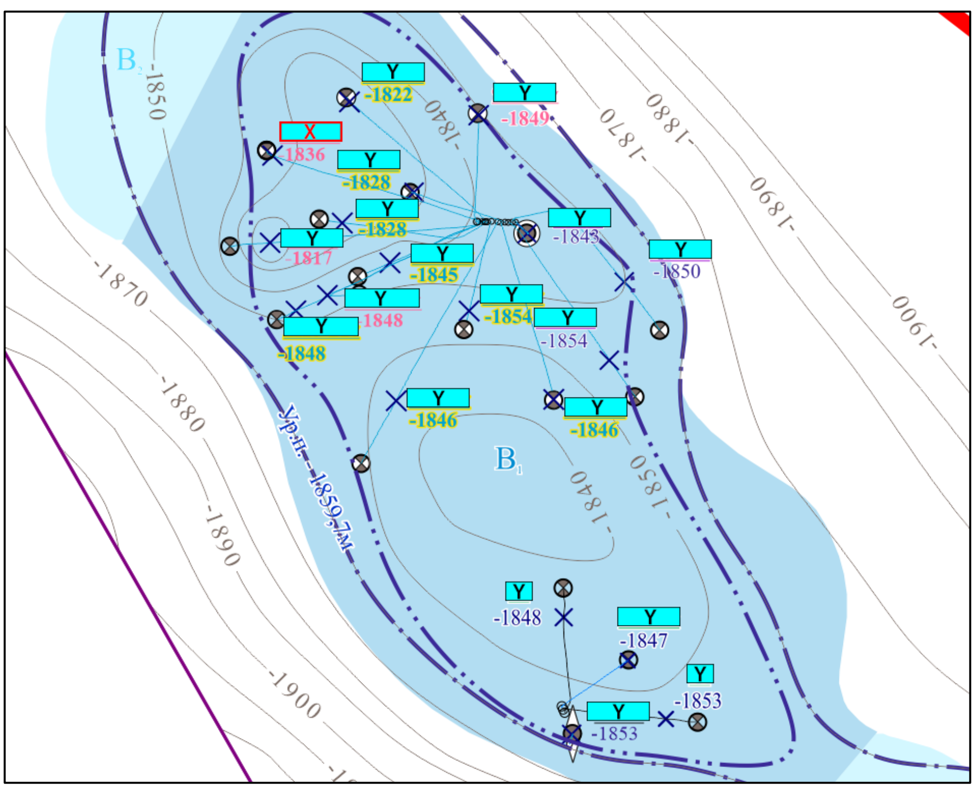

Figure 1 – Structural map of Serpukhovian Stage

Works were done in the carbonate formation of geologically age called Serpukhovian Stage, the substage of Mississippi Subsystem. The reservoirs are mostly secondary dolomites and, to a lesser extent, relic-organogenic-detrital limestones, irregularly dolomitized. The main reservoir is roof pool, partially lithologically restricted. Effective oil-saturated thicknesses vary from 1.6 m to 5.0 m. The porosity of oil-saturated reservoir rocks varies from 8.4-23.7% and averages 16.3% (fig. 2).

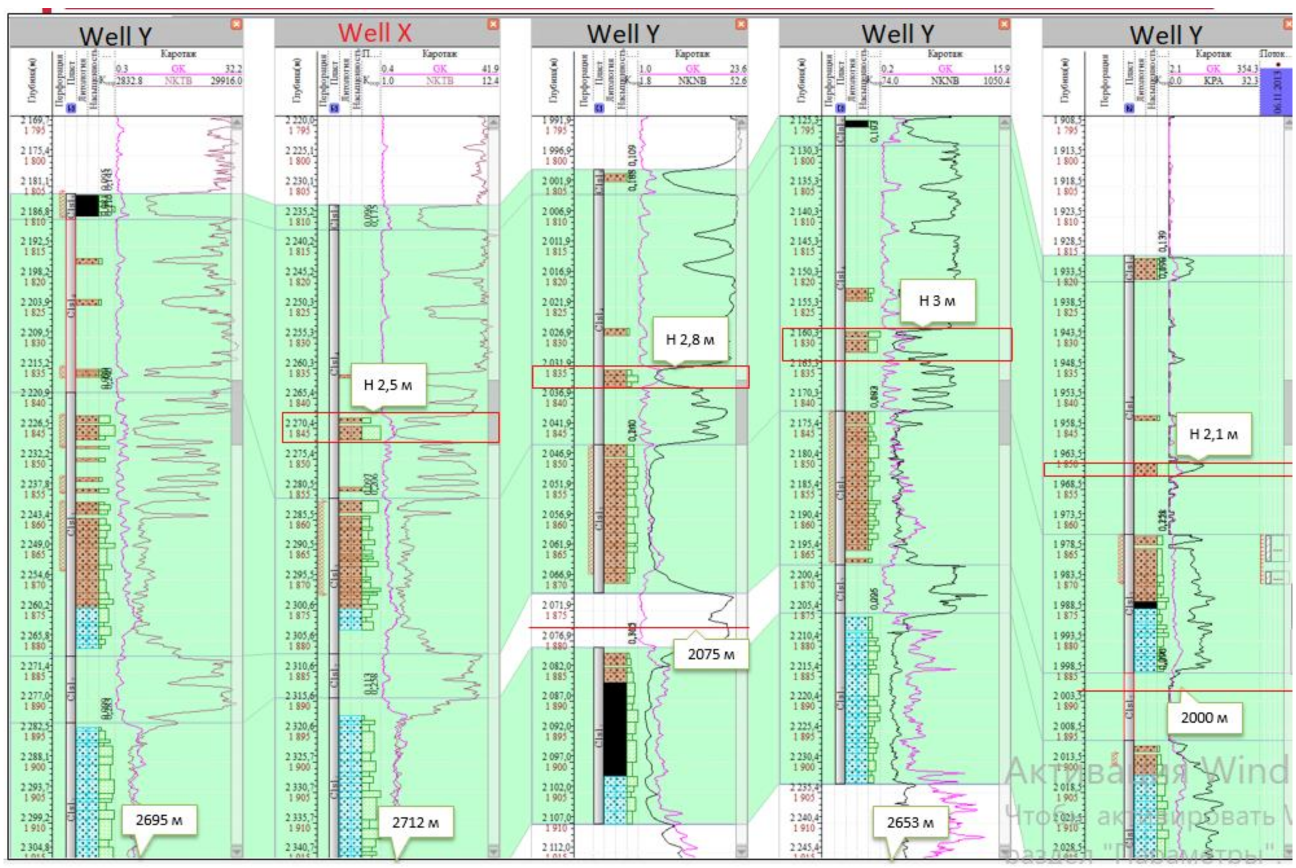

Figure 2 – Well section of Serpukhovian Stage

Goal

The objective was to significantly increase production from mature field with the minimum possible CAPEX, avoiding expensive drilling of new wells. The technology of directional radial drilling was used for production increase from wells with nearwellbore damage and/or low permeable reservoirs of any type. Present paper describes the increase of oil production rates by the application of a new reservoir access technology to a low-permeability reservoir by mechanically drilling three radial channels. After the removal of the anchor after radial drilling, production from the existing wells was significantly improved by the the radial channels. Figure 3 shows the development scheme of the analyzed field. It should be noted that this article provides an example of increasing production through directional radial bit-drilling in the well X.

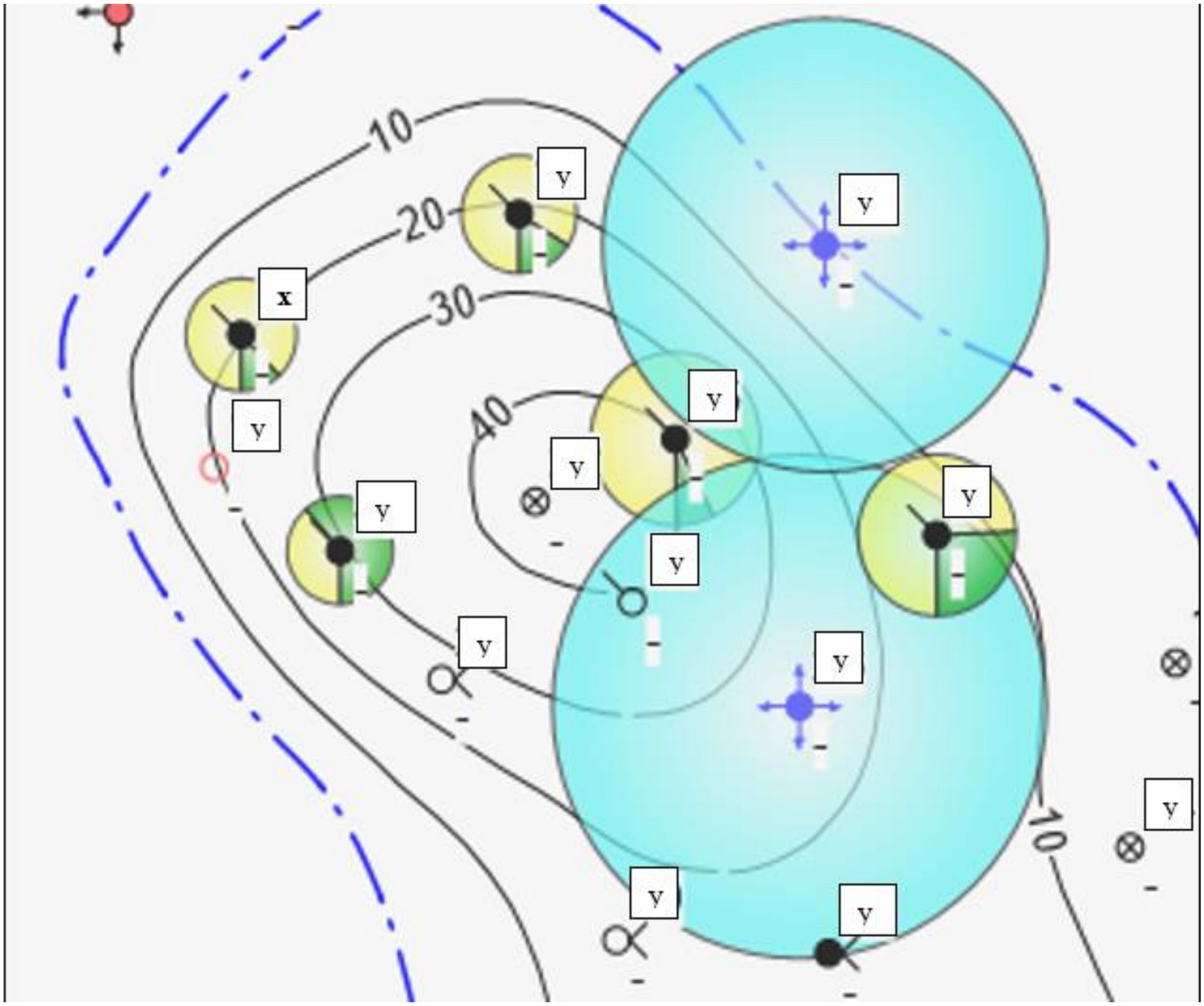

Figure 3 – Development scheme of the analyzed field

Tasks

The authors successfully solved the following tasks:

1. selection of well candidates for stimulation;
2. directional radial bit-drilling;
3. estimation of directional radial bit-drilling technology effectiveness in terms of oil production;

A network of 3 channels, each 14 meters long, were drilled using a directional BHA with a small diameter downhole motor that was deployed using a workover hoist. A survey was performed on each drilled channel to confirm the desired channel placement. After successfully extracting the anchor module from the well a well test was performed. The production rate was improved by 250% and the operation was considered very successful. The experience obtained showed that the technology is applicable as an intensification method in low thickness reservoirs.

This was the first time the technique was used in a thin target layer, and it was also the first time a retrievable anchor module was used. This paper shows that the technology of directional radial drilling provides superior reservoir exposure and drainage that results in significant increases in oil production from mature fields. This is a unique technology that has proven valuable for thin layer tight reservoirs that are under-performing.

Standard radial drilling technologies hydraulically jet small diameter channels that aren't directionally controlled and cannot be surveyed or re-entered. These standard techniques often exit the reservoir into non-productive and/or problematic gas/water zones, therefore directionally controlled radial drilling technology was selected. A special anchor assembly and deflection device with a directional BHA was deployed from a workover hoist to accurately drill a network of 69-mm diameter channels with a length of up to 15 m into the target reservoir. The deflection system allowed selective re-entry into each channel for survey and formation evaluation and allows deployment of slotted liners or screens.

Perfobore Mechanical Radial Drilling Technology

Perfobore is a technology of a mechanical radial drilling with using of slim mud motor. The technology allows drilling a network of radial channels up to 15 m (49 ft) long with up to 4 channels of different trajectories on one level.

Technical system (TS) Perfobore is manufactured in a modular construction for ease of assembly at the wellhead area and increased operational efficiency. The main elements of the TS are: pipe pusher connected at the top with an overflow valve module, and at the bottom with a guiding device connected by means of a hydraulic pusher (operating in damper-oscillator modes) and a flexible pipe assembly with a small-sized (non-standard) sectional mud motor, and drilling bit (milling cutter for window cutting). A special whipstock and an anchor module with an orienting funnel are connected from below to the pipe frame (fig.4).

Main elements of the TS are the working bodies of the mud motor, which create the necessary torque to drive the milling cutters that cut windows in the casing string, or bits that drill the rock along the super-small radius of the channel curvature. There was developed a methodology to select the optimal variant of the working bodies of the universal high-torque slim mud motor for TS Perfobore. It allowed to construct sectional motors with the size of 43-54 mm (1.69 – 2.12 inch) with improved characteristics in comparison with serial mud motors. These were tested were tested on the test-bench and were successfully applied in well works [1,2].

The first stage of the technology involves the run and orientation of the anchor module. After the anchor has been run, the anchor is positioned in depth by GR and collar locator and oriented in azimuth. Then after the anchor is positioned and oriented, it is set up by pressuring up. The second stage is milling the window. The milling module is run into the well and connected to the anchor module. After window cutting the milling module is run out the well. And the third stage is drilling the channel. The drilling module is run into the well and connected to the anchor module. After drilling the channel, the drilling module is run out the well.

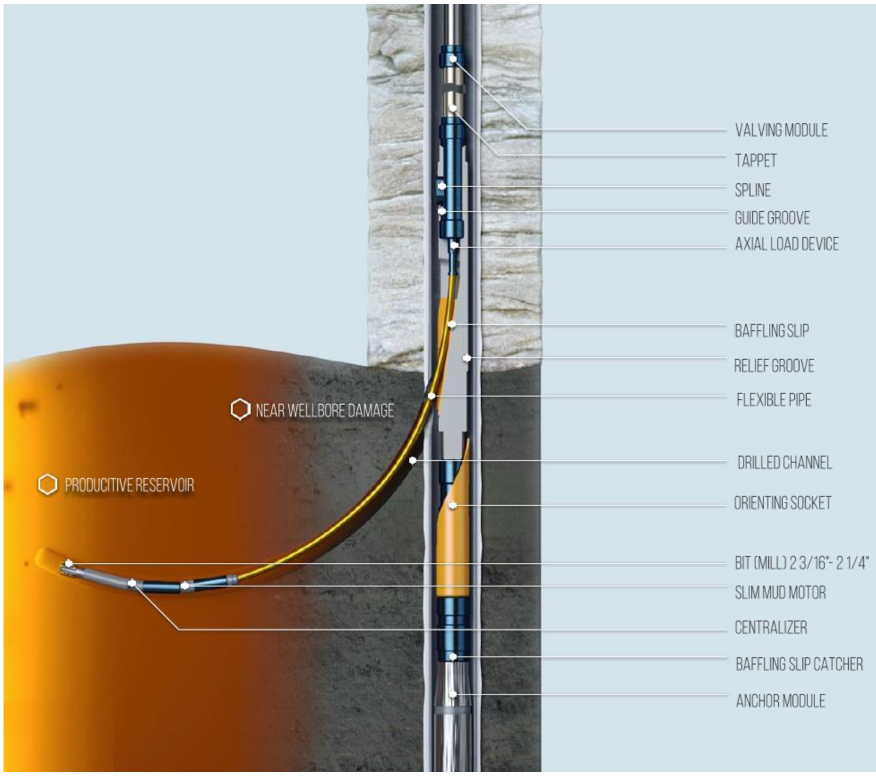

Figure 4 – Main elements of TS

The main advantages of the technology are controlled trajectory of mechanical drilled channels and the possibility of re-entry into the channels. The technology can be applied both in vertical and horizontal wells.

Due to possibility of re-entry into the channels, it was proposed to combine the technology of mechanical radial drilling with acid jetting. A special jetting gun was developed for this purpose. This jetting gun has four nozzles through which acid is injected at a flow rate of 100 m/s. After channel drilling, the jetting gun is run into the well and connected to the anchor module. After connecting, the jetting gun is run into the drilled channel. Acid can be injected through each meter inside the drilled channel. The treatment duration of each point is 30 minutes. In addition to the effect of dissolving the formation, the additional caverns, which in theory are up to one meter long, are washed out. The caverns are washed out with a pear-shaped, narrow cone facing the drilled channel [3].

Job Procedures

The task of the work was to drill on one level three radial channels, each 14 m (46 ft) long, through the milled windows in the casing column. Interval for the drilling was 2270-2273 m. After drilling the channels it is necessary to perform inclinometry to confirm the planned trajectories.

To design the channels, the wellbore inclinometry data, the wellbore plan, and the Gamma Ray and collar locator data are needed. The Gamma Ray and collar locator data are needed to exclude window milling in the casing collar interval. The BHA used in this work allows drilling channels up to 14 m long with a radius of curvature of 8 m. The intensity of the set angle is about 8 degrees per m. This makes it possible to achieve a displacement from the well of 9.5 m. Given that the oil reservoir is only 2.5 m thick, the windows should be cut about 5 m above the reservoir top (fig 5,6).

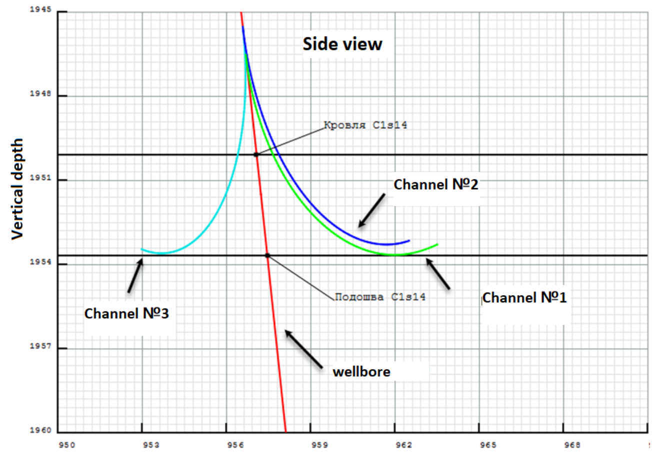

Figure 5 – Trajectories of channels (side view)

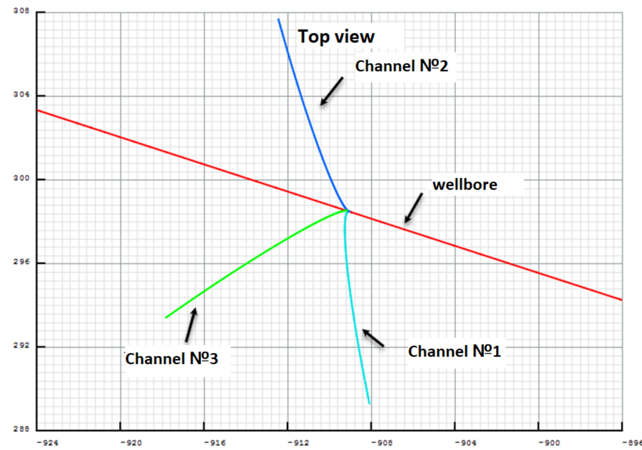

Figure 6 – Trajectories of channels (top view)

First step – an anchor setting. Assembling and run-in hole of the anchor module was made. Geophysicists made of depth positioning using a marker joint according to geophysical well logging (GR, CCL) and the anchor orientation by azimuth. After the depth positioning of a marker joint anchor module has been run at the required depth 2,266.69 m with subsequent setting up by pumping of technical fluid into a tubing and pressure maintaining (60 atm.) by cementing truck (CT-320). The strength of the anchor was checked by unloading the weight of the tool by 5 tons. The conclusion - the anchor was successfully activated. Undocking of the transportation device (nipple) from the anchor occurred by pulling the tubing up to 28.5 tons with a dead weight of 23 tons.

After lifting the nipple, the assembly (technical system "Perfobore") for window milling was carried out. Bottomhole assembly (BHA) was lowered to depth 2,266 m, before fixing the grip holder, the performance of the mud motor was checked under 3 liters per second, the unloaded pressure was 45 atm. After making certain that the mud motor works properly, the BHA was connected with the anchor module and fixed in it with a check of fixation by pulling 1 ton over a dead weight. The milling process took about 9 hours, taking into account the time of flushing back in the window interval under the following modes: weight on mill is 0.1-0.5 tons, pump flow is 3-3.3 liter per second, pressure is 42-53 atm, rate of penetration (ROP) of milling was 0.145 meter per hour. Window interval 2264.88-2265.68 m. Milling control was carried out by differential pressure and weight, chip collection was performed on magnetic panels installed in the receiving tank. Fluid loss during milling operation was 4 cub.m. The BHA was disconnected from the anchor module when the tubing was tensioned by 9 tons over a dead weight. Then the BHA of the TS "Perfobore" for milling was lifted to the wellhead and rigged down (fig. 7).

After lifting and rigging down the BHA for milling, the BHA for drilling with 14 m long channel and 69 mm bit diameter. The RIH was made to the required depth of 2,266 m with a speed limit of 0.2 meter per second. The BHA was connected with the anchor and the fixation was checked by tension by 1 ton, which indicates a proper fixation. The drilling process took about 13 hours, taking into account the time of flushing back in the channel under the following conditions: weight on bit is 0.1-0.5 tons, pump flow is 2.5 liter per second, pressure is 38-48 atm. The BHA was disconnected from the anchor when the tubing was tensioned by 6 tons over a dead weight. Then the BHA of TS "Perfobore" for drilling was lifted to the wellhead and rigged down (fig. 8).

Figure 7 – Traces of oil on the mill

Figure 8 – Traces of oil on the drill bit

After lifting and rigging down the BHA for drilling, the BHA for directional survey was assembled to record channel trajectory. The RIH was made to the required depth of 2,266 m with a speed limit of 0.2 meter per second. The BHA was connected with the anchor at the depth 2,266.69 m with unloading for 4 ton over a dead weight. Fixation by tensioning for 2 tons is checked. The channel inclinometry was recorded, after that the BHA was disconnected from the anchor when the tubing was pulled by 56.5 tons and the BHA was lifted to the wellhead.

The construction of the second and third channels was carried out in a similar way.

After the construction of the three channels and their directional survey, retrieving of the anchor was performed. The BHA was assembled to retrieve the anchor. The RIH of gripper to the “zero point” of the anchor at 2,266.69 m and connected by unloading the tubing. The anchor was deactivated by pulling the tubing string. This was evidenced by a sharp decrease in weight to a dead weight. The anchor was pulled out of the well.

Results

Before the radial drilling, the well was in operation with the parameters: liquid rate 12 m3/day, oil rate 10 tn/day, water cut 3% (table 1). The planned parameters were as follows: liquid rate 23 m3/day, oil rate 19 tn/day, water cut 10%. After the radial drilling operations, the well was started with the following parameters: liquid rate 40 m3/day, oil rate 33 tn/day, water cut of 10%. The factual oil flow rate increase exceeded the planned one by 2.5 times.

Table 1. Results

Parametrs before work			Planned parameters			1 month after work			2 months after work			3 months after work		
Liquid rate, m3/day	Oil rate, tn/day	Water cut, %	Liquid rate, m3/day	Oil rate, tn/day	Water cut, %	Liquid rate, m3/day	Oil rate, tn/day	Water cut, %	Liquid rate, m3/day	Oil rate, tn/day	Water cut, %	Liquid rate, m3/day	Oil rate, tn/day	Water cut, %
12	10	3	23	19	10	40	33	7	33	29	2	33	27	9

After the radial drilling operations, the well test was performed to determine the productivity of the well (fig. 9). According to the interpretation of well test data, the well skin after directional radial grilling is -4.39.

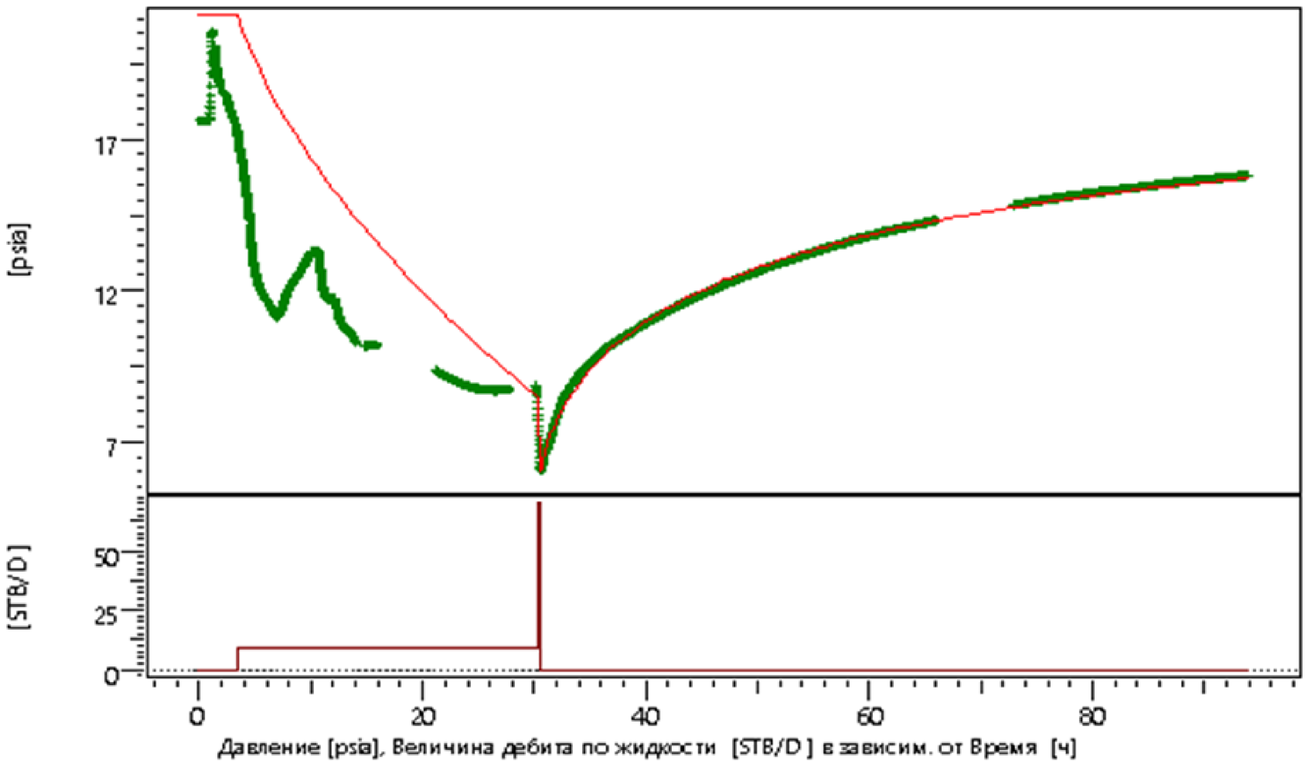

Figure 9 – Pressure variation graph at the measuring point

Conclusion

- Directional radial drilling technology Perfobore helped to increase well flow rate by three times, while the plan was to increase it by two times.
- The geological success of the work was confirmed by the conduct of well test.
- Planned channel geometry was confirmed by directional logging of each channel.
- This was the first time the technique was used in a thin target layer – the net pay thickness was 2.5 m.
- This was the first time a retrievable anchor module was used.
- Next year it is planned to perform directional drilling on two other wells to increase the production and increase the scope of the technology application.

Acknowledgments

We thank Lukoil-Komi management for support and allowing publication of the data including in this paper.

References

1. Lyagov I.A., Baldenko F.D., Lyagov A.V., Yamaliev V.U., Lyagova A.A. UDK 622.243.92 «Methodology for calculating technical efficiency of power sections in small-sized screw downhole motors for the «Perfobur» system».

2. Lyagov I.A., Vasilev N., Reich M., Mezetti M. Oil Gas European Magazine. Volume 40. 3/2014. «Analytical Research and Experimental Tests on the Technology for Drilling Small Diameter Channels with small Radius of Curvature».
3. Lyagov A.V., Malikov E.L., Kuznecova N.YU., Shamov N.A., Lyugova M.A., Simonov A.S. UDK 622.276.245.142. «Improving the technology of casing perforation and well completion».