OTC-31705-MS

Adapting the Technology for the Construction of Taml-1 Level Multilateral Wells at the Novoportovskoye Field for Separate Production Accounting for Each Reservoir

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 DOI 10.4043/31705-MS

This paper was prepared for presentation at the Offshore Technology Conference held in Houston, TX, USA, 2 – 5 May, 2022.

Abstract

Summary: The Novoportovskoye field is characterised by a mainly complex geological structure and the presence of remaining reserves. The situation is further aggravated by significant oil reserves occurring right under massive gas caps. To make HC recovery profitable in such geological settings, new technologies are required.

This paper provides an insight into the case of creating a multilateral well based on a new TAML-1 level completion solution utilising the properties of the impermeable top of one bed and the dynamic quantum PLT to measure production from each formation separately in accordance with existing regulations.

Introduction

The Novoportovskoye field is the largest oil and gas condensate field on the Yamal Peninsula outside the Arctic Circle. Considerable oil and gas reserves were proven there as early as in 1964. However, full-scale development was impossible for a long time due to the lack of transport infrastructure and complex geological settings.

During the exploration, most of the wells drilled in the first three years turned out to be waterflooded or did not reach productive formations. Wells drilled in the top of the target structure penetrated pay formations at the highest hypsometric elevations and showed gas inflows with a high condensate content during tests. Based on these results, the Novoportovskoye field was categorised as a gas condensate field. Subtle signs of oil detected during tests in some wells suggested the presence of oil rims.

Commercially viable reserves of oil, gas, and condensate are concentrated in terrigenous deposits of the Lower Cretaceous and Jurassic strata at depths from −1,850 to −2,020 m.

The formations are mainly marine deltaic sandstones interlayered with clays and dense carbonated interlayers with permeability from 1 to 30 mD. The Upper Jurassic rocks also contain some coal deposits of continental origin.

In the eastern part of the field, numerous tectonic disturbances are found that lead to high-amplitude layer displacements from several to dozens of meters. All productive reservoirs in the dome are represented by a gas cap with commercially viable reserves of natural gas (Figure 1).

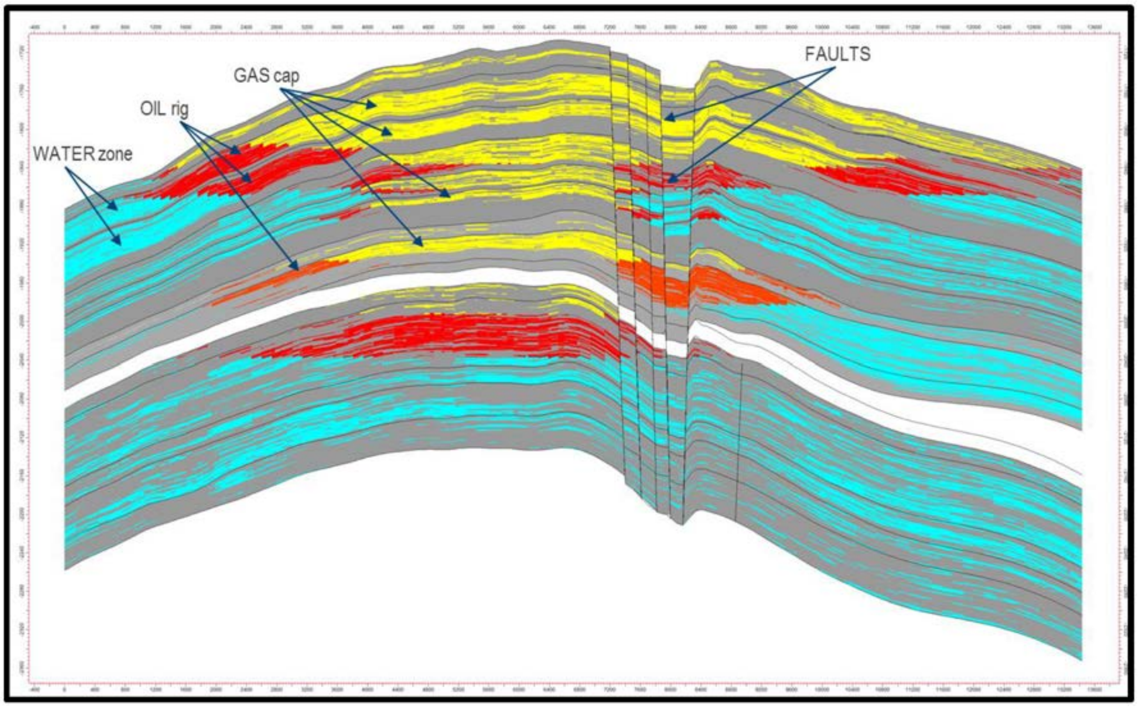


Figure 1—Cross-section of the dome structure of the Novoportovskoye field

At the beginning of the project, the oil rim development was mainly targeted at productive reservoirs with a high permeability of 25—100 mD and with a reservoir thickness up to 35 m. However, the main amount of the reserves in the formation is concentrated in Upper Jurassic deposits up to 25 m thick characterised by a high degree of vertical geological heterogeneity, reservoir compartmentalisation, and permeability not exceeding 5 mD, as well as in thin Lower Cretaceous formations with a thickness of up to 5 m and a permeability of 10—15 mD.

The development of such complex fields requires new approaches to drilling, exploration, and field development since commonly replicated solutions are uneconomical due to the high cost of drilling technologies. In the current economic settings, such oil and gas production just doesn't pay off.

Traditionally, the wells drilled in the Novoportovskoye field have a multiple-string configuration, with the production string run into the top of the target productive reservoir. The horizontal section is from 1000 to 2000 meters long.

Peculiarities of well design

Along with traditional wells, multilateral wells have been extensively drilled in order to expand the drainage area. By the end of 2021, 75 multilateral wells were completed using the TAML-1- level solution. Each well had from two to five cased laterals, with all the laterals located within one productive reservoir.

Given the vertical heterogeneity and the relatively high costs of well drilling, there is no economic viability in drilling individual wells in order to bring low productivity areas into production. The multi-disciplinary team of the operator company was faced with the task of increasing the oil recovery factor while finding the most cost-effective solution. After analysing the existing multilateral well construction technologies, it was concluded that using the TAML 2-5 level technologies would be unreasonable due to their high cost. It was decided to develop a custom solution. As a result, a conceptual design was developed for multilateral well completion using the rock properties in the reservoir top interval and a set of swell packers to create an isolated branching point (Figure 2).

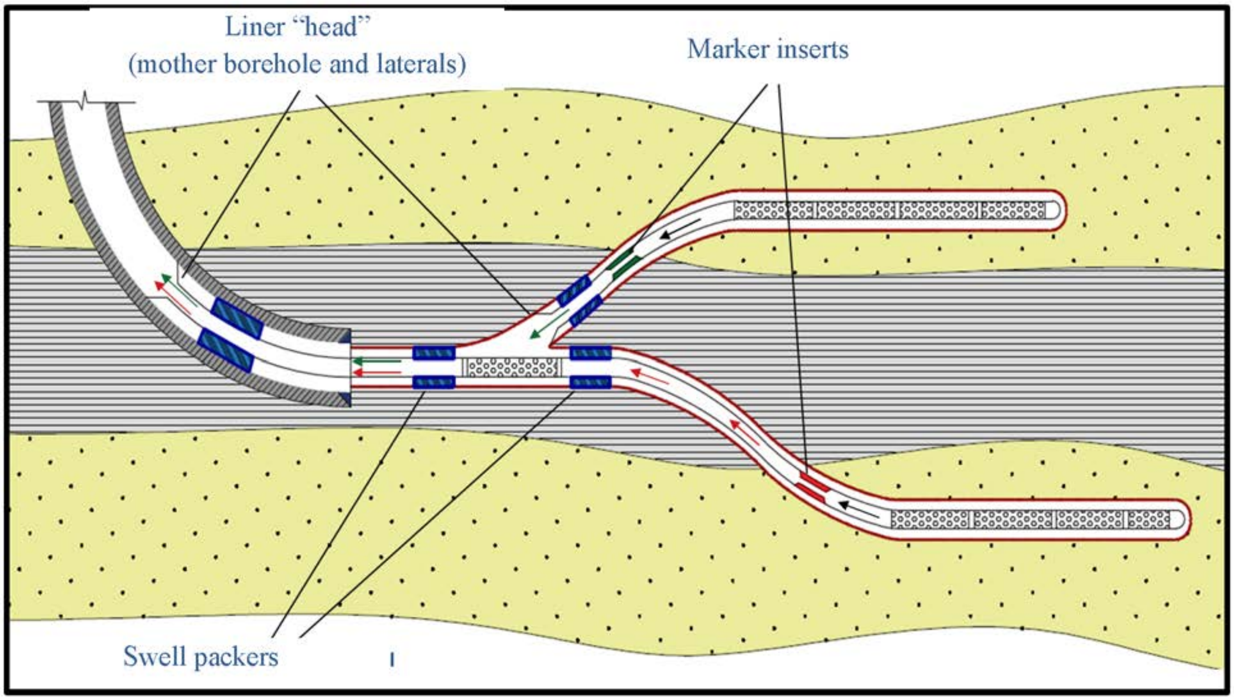


Figure 2—Conceptual TAML-1 well completion design

In this approach, the shoe of the production string is first placed into an impermeable interlayer between two target productive layers. Then the first lateral is sidetracked toward the upper layer and is subsequently fixed with a filter liner. The design of the liner includes blind pipes, a swell packer and an insert with marker tapes. The "head" of the liner is a left-right thread sub providing for reliable and cheap disconnection with the running string.

Sidetracking toward the underlying layer is done using the BHA for subsequent drilling by keyseat reaming without involving additional equipment. Once the target depth is reached, the BHA is lifted and the sidetrack is completed with a liner. The liner consists of (bottom-up) a shoe, well screen pipes in the reservoir interval, and blind pipes in the transition area to an impermeable layer having an insert with marker tapes. The branching point interval consists of a single perforated pipe and blind pipes with a standard liner hanger in the production string and is isolated by swell packers. This design enables measuring the contributions of each lateral individually (by cutting off one or another lateral).

If a well penetrates more than one reservoir, production from each of them must be accounted for individually in accordance with the legislation. For these purposes, dynamic quantum PLT was selected, since it has no limitations with this well design, unlike conventional logging methods.

Dynamic Quantum PLT Without Well Interventions

The dynamic quantum PLT technology involves the use of quantum marker reporters — high-precision indicators of reservoir fluid inflow. A composite material with markers is placed into special downhole inserts installed in the lower completion of a multilateral well (Figure 3). The marked material is a plastic composite, i.e. marker tapes that release indicators into the reservoir fluid at a stable rate and duration. Different types of marker tapes - oleophilic and hydrophilic - are combined, so the markers are released exclusively into the target reservoir fluid phase - oil and water, respectively. An individual marker code is responsible for providing data to evaluate the individual contribution of each lateral.

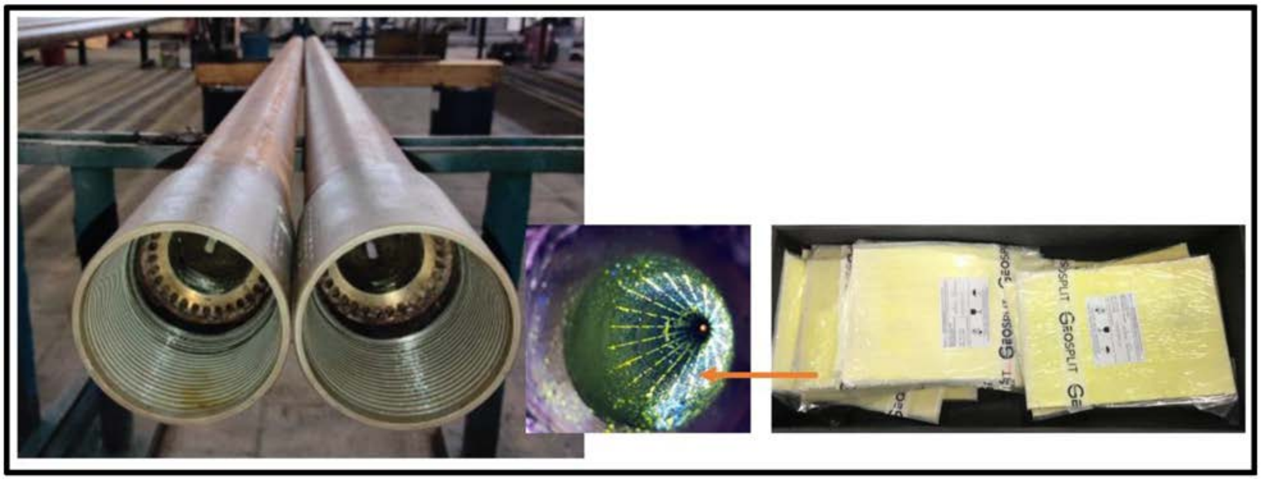


Figure 3—Downhole quantum marker inserts with marker tapes

After the liners with quantum marker inserts are run downhole, the latter are used then in subsequent production surveillance. Reservoir fluid is sampled from the wellhead and the samples are analysed using a flow cytometry analytical complex. According to this method, dispersed media are analysed on a particle-by-particle basis using light scattering signals. It helps identify the quantitative distribution of oil and water markers of each code with high accuracy.

The data of long-term dynamic quantum PLT in a producing well, coupled with the analysis of the historical performance of the target well and the nearest-neighbor wells, provides a basis for developing recommendations on how to optimise development of complex fields.

Dynamics of the inflow profile for a one-year surveillance period

Dynamic quantum PLT in a bilateral well of the Novoportovskoye field was conducted from December 2020 to October 2021. Horizontal laterals of the well pierce a fault trap bounded by two faults forming a structure in the shape of a step fault (Figure 4). The target layers are separated by impermeable interlayers predominantly composed of clay. Due to this, production can be accounted for separately for each lateral. Since the trajectory of the lower horizontal lateral passes near the water-oil contact, there are risks of water-flooding during production.

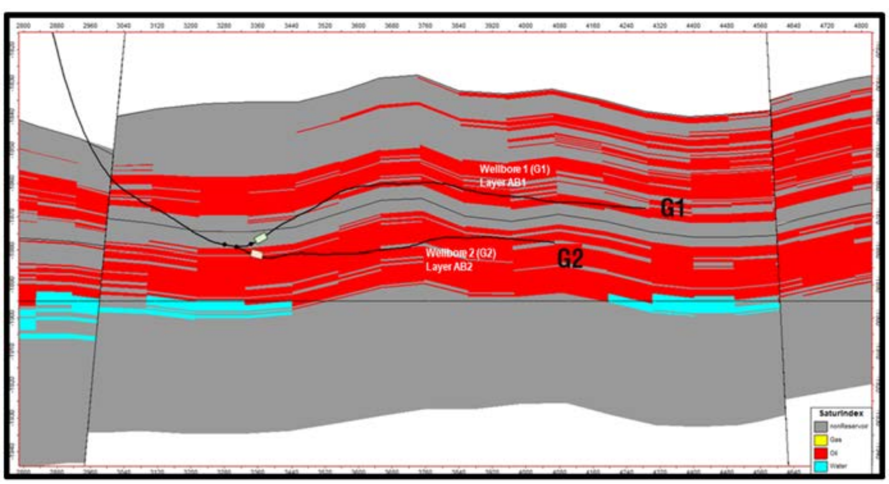


Figure 4—The subject horizontal well profile according to the saturation cube

During the entire time of surveillance, 8 surveys were conducted to obtain the distribution of the laterals' contribution for each period (Figure 5).

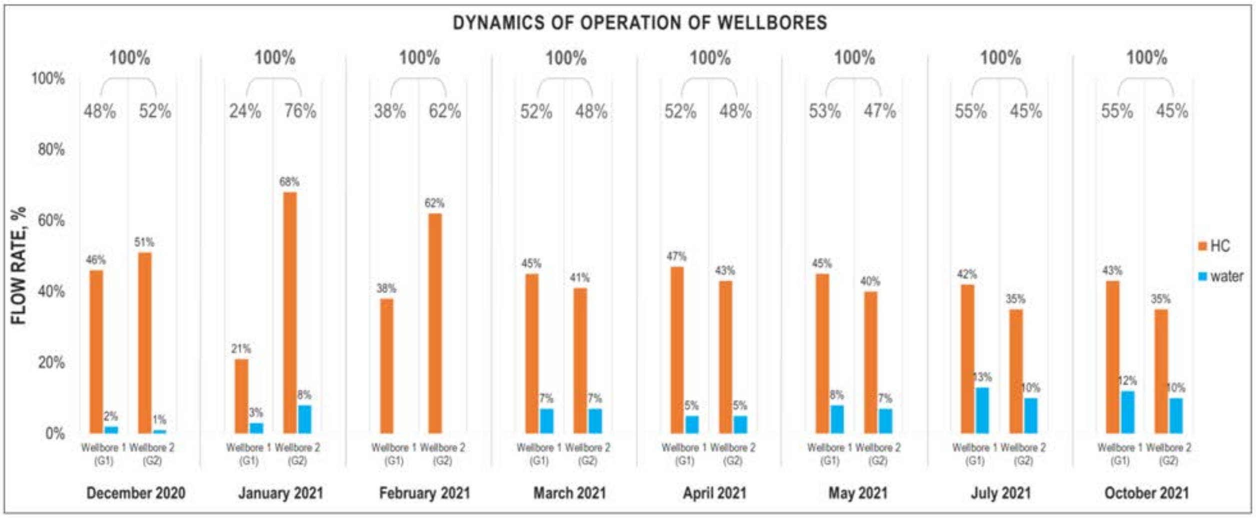


Figure 5—Dynamics of the performance of well No. XXX1 laterals

According to the data of dynamic quantum PLT and the analysis of the field geological settings, including the reservoirs, the following observations were formulated. Uneven performance of the laterals was observed in the first three months of surveillance with a predominant contribution of horizontal sidetrack 2, which is due to a non-steady fluid flow along the reservoirs. A relatively uniform production starts from the next quarter, with a slight predominance of the contribution from horizontal lateral 1. At the same time, water cut in the formation fluid is growing gradually during well operation.

The marked subject well No. XXX1 extends over the area marked by multiple faults. A water-oil contact is located to the east of the subject area. A probable system of conductive cracks could trigger a water flow process as reservoir pressure in the eastern part of the subject field was decreasing, inter alia, in the marked well drainage area.

Turning from relative values (the percentage distribution of the performance by laterals) to absolute figures (cubic meters per day), reservoir energy tends to decline in the course of well operation (Figure 6).

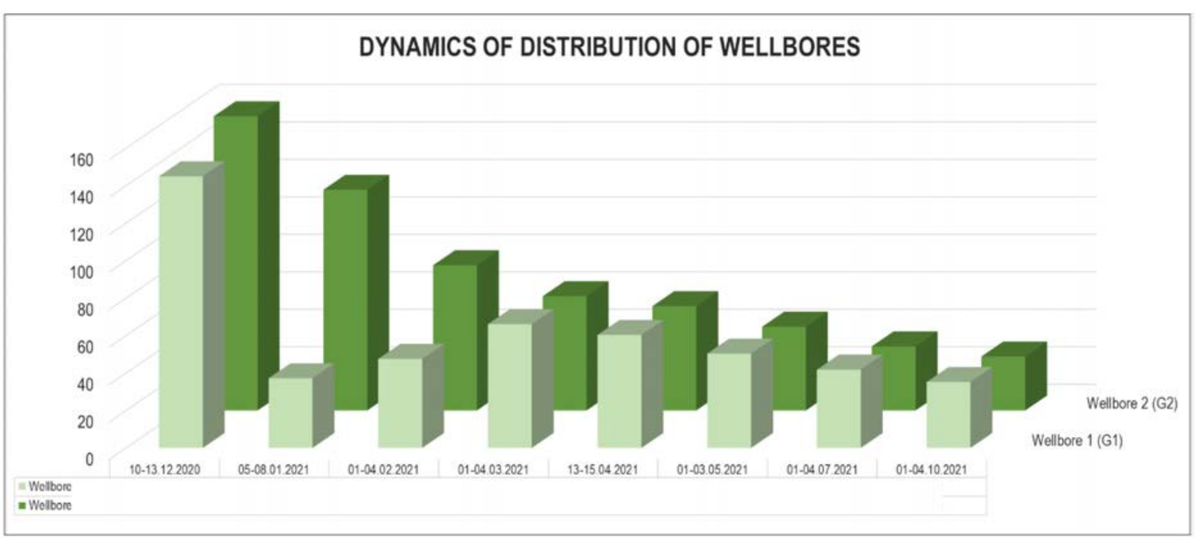


Figure 6—Dynamics of lateral performance in absolute values

Absolute figures of the production dynamics reveal a significant discrepancy in the performance of the laterals in the initial months of production. Thus, a sharp drop in the fluid flow rate in January 2021 (subsidence) observed in the performance of lateral 1 piercing the AB1 formation indicates the non-stationary nature of fluid flows in the drained area.

The dynamics of the performance of horizontal lateral 2 piercing formation AB2 demonstrates a gradual decrease in the fluid flow rate due to the presence of gas cap drive, in which oil is mainly propelled by the energy of the gas cap pressure. In this case, oil is displaced by the pressure of the expanding gas, which is in a free state in the top part of the deposit. The high permeability of formation AB2, several times the permeability of formation AB1, is a precondition for the most effective manifestation of the gas cap drive.

Production is complicated in such a case due to the fact that gas breakthroughs lead to uncontrolled waste of gas energy while reducing the oil flow. Therefore, it is recommended to continuously monitor production in the object under study and wells located near the gas cap.

The dynamics of reservoir performance (decreasing fluid flow rate and bottom-hole pressure) indicates a clear depletion effect in the well drainage area (Figure 7). This conclusion is also confirmed by the starting pressure after a long well shutdown, which has significantly decreased from the initial one.

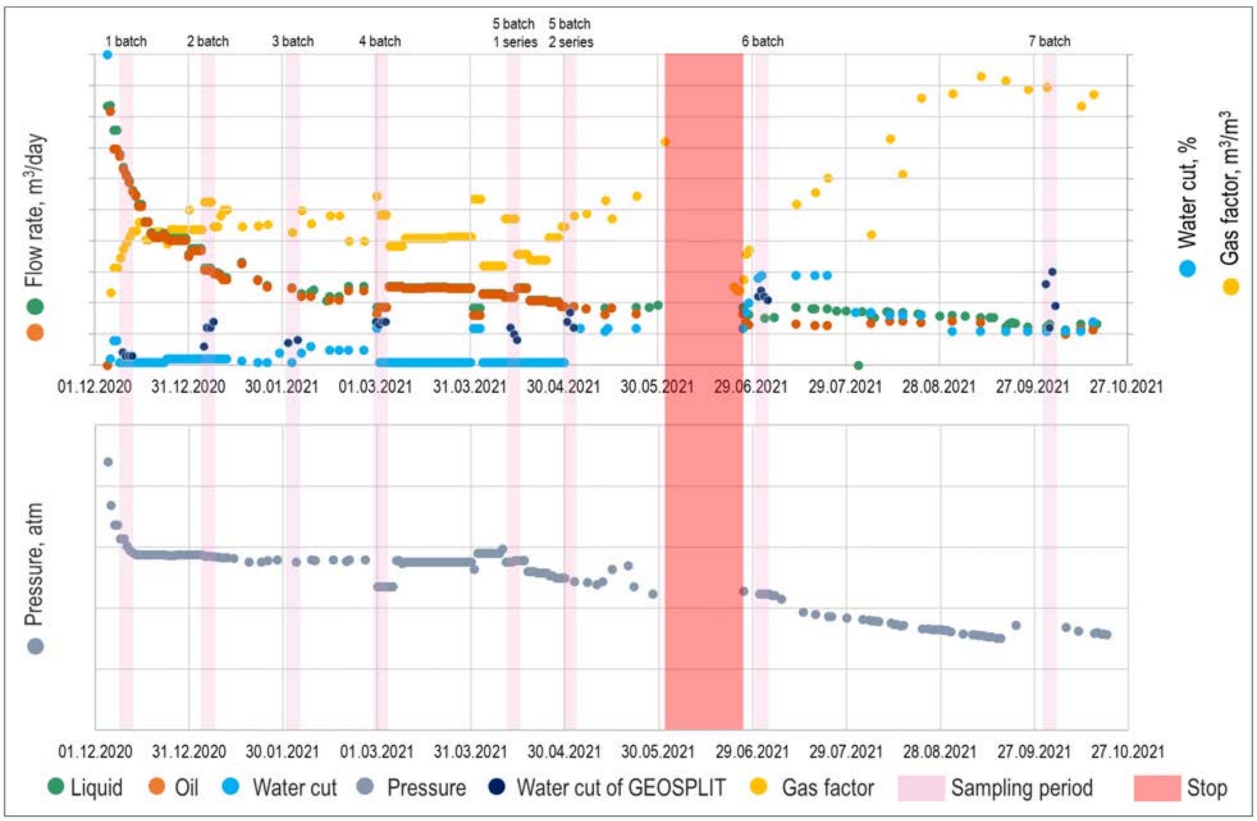


Figure 7—The history of the marked well No. XXX1 operation

The rapid increase in the gas factor since the well restart after shutdown is characterised by a decreasing gas-oil contact level. As the contact level decreases, the gas breaks through to the wells located closer to the gas pool boundary. In this case, it is important to optimise the energy loss from the expansion of the gas cap for the sake of cost-effective oil well operation.

A rapid increase in the gas factor may also be attributed to a change in the reservoir drive mechanism, namely, the transition from the gas cap drive to the dissolved gas drive. In the second case, oil is forced through the reservoir to the well bottoms by the energy of expanding gas bubbles as gas is released from oil. The reservoir drive mechanisms may naturally change due to a changing equilibrium in the reservoir, caused, in turn, by a decreasing bottom hole pressure.

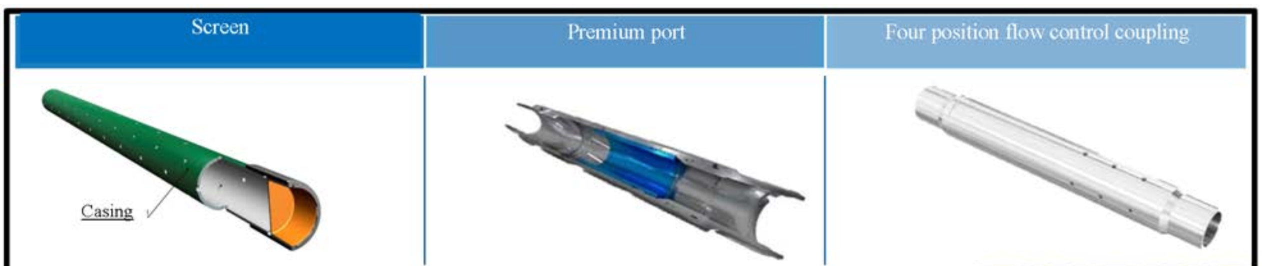
In addition to identifying the sidetrack performance distribution in the subject well for the purpose of split production accounting for two reservoirs with different porosity and permeability, data obtained using dynamic tracer-based production profile surveillance enables monitoring production indicators without well shutdown, as well as developing recommendations for its optimisation.

To reduce the water cut of reservoir products and the gas factor, it is recommended to consider the possibility of changing the reservoir drive mechanism in subject well No. XXX1 by slightly reducing depression, as well as controlling the bottomhole pressure to prevent well operation at the bottomhole pressure below the saturation pressure.

Conclusion

The multilateral well in question was drilled without breaching the construction schedule, in accordance with the planned profile, and completed without an accident. The total flow rate of a multilateral well is the total of the flow rates of two individual wells for the same purposes. That said, capital expenditures (CAPEX) and construction time were reduced by almost 38%.

The design of the branching point enables selective cut-off of both the lateral (using a profile packer) and the mother borehole (bridge plug) in the event of an undesirable fluid breakthrough. At the same time, there is still a possibility to elaborate the branching point design by using a controlled coupling instead of a perforated pipe (Figure 8).



	Screen	Premium port	4-position flow control coupling
Need for activation	No	Optional	Optional
Requirements for positioning in the well	Mild	Strict	Strict
Cost	Low	Medium	Medium
Availability	Yes	Yes	No
Number of open/closed positions	One	Two	Four (including partial)
Possibility to cut-off	Conditionally (using a patch/ squeeze cementing)	Yes, tong for coiled tubing/workover	Yes, tong for coiled tubing/workover
Possibility of alternate sidetrack operation	No	Yes	Yes
Possibility to control depression on sidetrack	No	No	Yes

Figure 8—Structural elements of the branching point

The use of a controlled coupling opens up extensive possibilities to replicate the technology both in terms of the construction of multilateral wells with production from up to three adjacent layers, and multilateral wells in one pay reservoir leveraging the possibility of controlling the production from individual laterals (Figures 9 and 10).

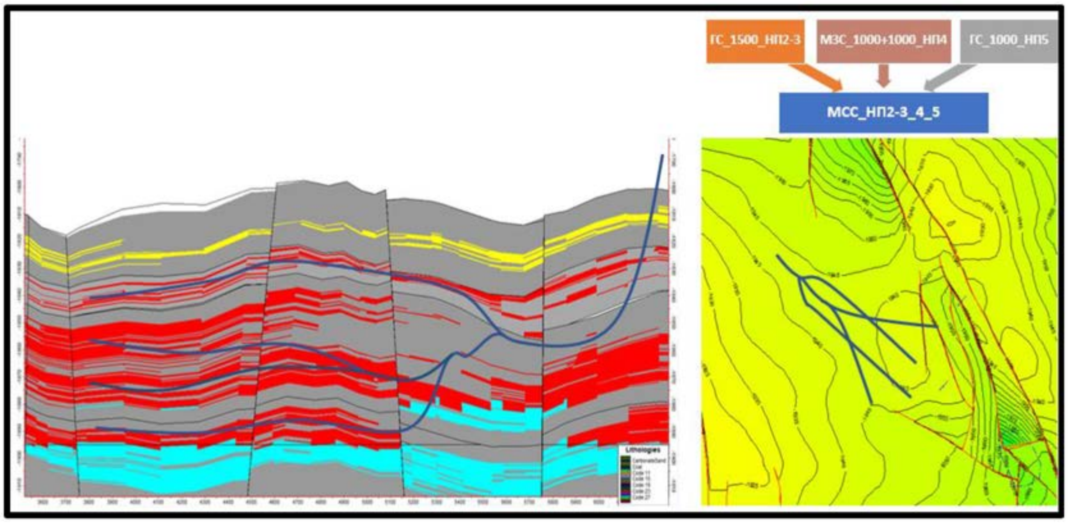


Figure 9—Technology replication potential for multilateral wells (Option A)

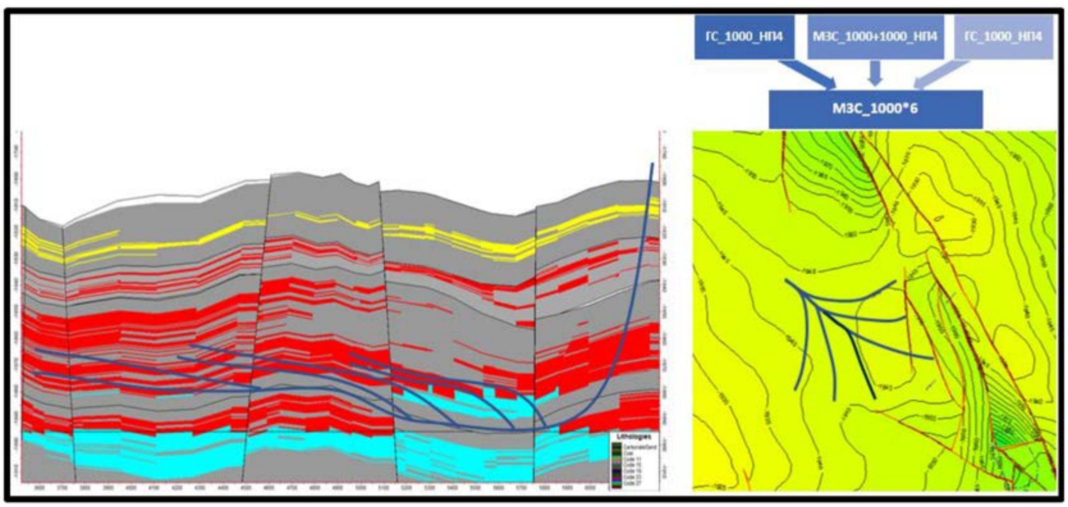


Figure 10—Technology replication potential for multilateral wells (Option B)

In addition, the design enables separate production accounting for each reservoir while continuing production. Moreover, the costs of interpreting samples with quantum markers on a regular basis are offset by reduced operating costs for the pumping unit and the costs for workover crews.

Dynamic quantum PLT efforts in the subject reservoir mentioned in this article are conducted on a quarterly basis. The accumulated data and information from each new study period enable the development of new recommendations and a target-specific approach to optimising field development at the Novoportovskoye field.

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