An analysis of the effectiveness of hydraulic fracturing at YS1 of the Northern field

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Abstract. There are many methods of enhanced oil recovery and stimulation of oil inflow, and in order to find their most effective application, it is necessary to study the object of works, candidate wells, as well as their impacts on these wells. One of the methods of production intensification, which makes it possible to improve profitability of oil extraction, is hydraulic fracturing.

1. Introduction
For the first time, the hydraulic fracturing method was applied in the Northern field in 1993. In 2009-2013, the BS11 and YS1 facilities were commissioned. The share of the YS1 in the field’s production has significantly increased and amounts to 28.1%, while the share of the current recoverable reserves is 27.1%. This was achieved due to advanced technologies used for drilling horizontal wells using the multi-zone hydraulic fracturing method. As of 01.01.2014, 2,467 wells were put into operation after their hydraulic fracturing (Figure 1, Figure 2):

![Figure 1. Distribution of hydraulic fracturing volumes by years and categories of wells. Northern field](image-url)
Figure 2. Distribution of hydraulic fracturing volumes by years and objects. Northern field

YSI. The hydraulic fracturing began in 1993. As of 01.01.2014, 429 treatments were performed (including 96 - at the operating fund, 227 - at directional wells from drilling, 24 - during sidetracking of the second wellbore, 47 - at horizontal wells, 7 - when transferring to another horizon, 1 - with the addition of a new object to previously operated formations, 18 - at injection wells);

An increase in the number of treatments has been observed since 2005; in 2013, the number reached 81. The dynamics of hydraulic fracturing operations is shown in Figure 3. The well stock coverage was 69% (Figure 4).

Figure 3. Dynamics of hydraulic fracturing at YUS1 by years

The average flow rate of fluid after hydraulic fracturing was 38.7 t / day, oil - 26.9 t / day, at the operating wells - 26 and 10.9 t / day, at drilled wells - 42.9 and 32.5 t / day, respectively. Additional oil production amounted to 5,671.3 thousand tons or 14.1 thousand tons per well (Figure 5), including:

- at operating wells - 697.9 thousand tons or 7.3 thousand tons / well, respectively;
- at WEM wells - 20.4 thousand tons per well;
- at new recompletion wells - 27.2 thousand tons or 3.9 thousand tons per well;
- at drilled wells - 4925.9 thousand tons or 16.5 thousand tons / well, respectively.

To predict the flow rate, empirical dependences on the effective reservoir thickness were used; the water cut was set according to the results of a geological analysis. For some wells, the indicators were adjusted based on the actual experience of using the hydraulic fracturing method at offset wells. When calculating additional oil production, we used the actual rate of a decrease in the effect for hydraulic fractured wells in 2010-2013.
Figure 4. Well stock coverage with hydraulic fracturing operations YUS₁
2. MES.

It is proposed to conduct pilot work at horizontal well No. 2010G using SurgiFrac technology - multi-zone hydraulic fracturing using a coiled tubing unit (fracturing fluid with proppant is supplied through the Hydra-Jet system: a high-pressure jet initiates a fracture, while fluid is fed through the annulus, which helps to expand the fracture)...

This technology has a high accident rate. In fact, a more reliable multi-zone hydraulic fracturing (MHF) technology was applied at YUS1 in horizontal wells, which implies the wellbore arrangement with a special multistage assembly at the construction stage. The liner arrangement allows us to divide the horizontal part of the well into several sections in an open hole and affect each interval. The main element of the system is circulation valves or couplings for interval fracturing, which were opened using a ball release system. The balls are dropped from the second interval; the first hydraulic fracturing is carried out without dropping the ball through the already pre-perforated pipe.

The HF technology by dropping balls is as follows: a device is installed at the wellhead, the device starts the first ball (of the smallest diameter), installed on the cylinder and activates the coupling, establishing a hydraulic connection with the annulus, hydraulic fracturing is carried out; the second ball is released (larger diameter), which simultaneously overlaps the previous interval (where the fracturing was carried out) and actuates its sleeve. In this sequence, all couplings are triggered towards the wellhead, and multi-point hydraulic fracturing is carried out along the entire wellbore. The annulus between two adjacent couplings is sealed with packers that swell in the presence of hydrocarbon or water.

For 2011-2013, at YS1, multi-zone 47 horizontal wells were fractured. The number of fracturing ports was 4-5. The average oil production rate was 78 t / day, which is three times higher compared to fracturing from drilling directional wells.

Thus, the multi-zone hydraulic fracturing technology is recommended for commercial implementation at the YS1 of the Northern field.

In addition, in 2012-2013, 4 wells (sidetracks with horizontal ends) No. 2108L, 2206L, 8333L, 6397L underwent multi-zone hydraulic fracturing using the Schlumberger AbrasiFRAC technology (hydrosand-jet perforation and stimulation of several intervals in one operation using coiled tubing.
which allows the multistage fracturing in small-diameter barrels and reduces time input). Hydraulic fracturing was performed in 3-4 intervals.

The length of one perforation interval was 5 m, the distance between the perforations was 65 - 100 m. When performing hydraulic fracturing using this technology, STOPs often occur (due to the complexity of hydrosand-jet perforation in the horizontal wellbore). The average oil production rate of wells No. 2108L, 2206L was 7.6 t / day, water cut was 73 and 90%, respectively; for wells No. 6397L, the average oil production rate was 8333L - 42 t / day and water cut was less than 10%.

Thus, the AbrasiFRAC multi-zone hydraulic fracturing technology is recommended in case of confident predictions about the nature of oil saturation and not advisable when drilling into zones with unclear oil saturation (high water-cut and for surrounding wells, the presence of technogenic fracturing due to previously performed hydraulic fracturing); in case of a low productivity factor along the sidetrack from drilling, it is more expedient to perform a less expensive “blind” hydraulic fracturing with a packer installed in the vertical part of the wellbore.

In addition, at YSı, nitrogen-foam hydraulic fracturing technologies and fracturing fluid with MPF were tested.

Nitrogen fracturing was performed on two wells, both operations were successful. After nitrogen fracturing with a foam rate of 30% (proppant weight 48 tons), Well No. 7621N yielded 22 tons / day for liquid and 19.3 tons / day for oil; an increase was 13.6 tons / day; the duration of the effect was one and a half years. At the same time, in 2009, the well was fractured during commissioning: 29 tons of proppant were injected, the input flow rate of fluid was 24 tons / day, oil - 12.5 tons / day; the less stable dynamics of work was observed (a decrease was 4 times per six months). After nitrogen fracturing with a foam rate of 50% (proppant weight 40 tons) Well No. 3627 yielded 51 tons / day for liquid and 31.9 tons / day for oil; an increase was 22, 6 tons / day, the duration of the effect was more than 3 years; at currently, the oil production rate is 24 tons / day.

3. Conclusion

Thus, the nitrogen hydraulic fracturing technology with a foam rate of at least 60% is recommended for the industrial use at YSı of the Northern field.

Analyzing the results of non-standard hydraulic fracturing technologies at the Northern field, the following recommendations were proposed for their industrial implementation. It is not recommended to limit the crack height by using low-viscosity surfactant-based fluids due to the lack of experience and inadequacy of the object. It is not recommend to reduce the relative phase permeability to water using a fracturing fluid with the addition of MPP (CW-Frac, Harriberton; PPM-1, solvent U-066 from Nalco Petroalliance; WCA-1, TricanVellServich; WLP-3700, KATConfet) or proppants with hydrophobic coating (ForeMPP, Schlumbrezhe) due to negative results of the laboratory tests. Reagents have a beneficial effect on fracture conductivity and matrix permeability. The use of reagents has a positive effect on conductivity of the fracture and permeability of the rock matrix if the fracturing fluid is foamed (nitrogen foam fracturing). It is not recommended if the fracturing fluid has a reduced polymer loading and self-dissolving organic fibers due to negative results of the laboratory tests. It is also not recommended to use preliminary isolation of water-cut intervals by pumping plugging compounds due to the high water cut before and after fracturing (more than 95%).

Despite the fact that measures taken at YSı in order to increase oil recovery and stimulate oil inflow have a positive effect, the most effective method is hydraulic fracturing. High rates of fluid and oil production rates were obtained for wells with a pronounced reservoir thickness (more than 7 m), high permeability and a low partition coefficient (less than 6 units). An important criterion for the successful hydraulic fracturing is the energy state of the area and a good hydrodynamic connection with injection wells.

At directional wells, an increase in fluid and oil production rates were observed with an effective reservoir thickness of more than 5 m, a proppant weight of over 50 tons and a proppant specific gravity of over 7 t / m.

The efficiency of multistage fracturing is influenced by the length of the horizontal section of the wellbore and the number of frac-ports. The recommended number of stages is five or more frac-ports.
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