EXPENDABLE TUBULARS AND CONTROLLED OIL AND WATER WITHDRAWAL INCREASE OIL FIELDS PROFITABILITY

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Abstract. The article describes the achievements of Tatneft PJSC in the field of isolating water inflow zones in horizontal wells by expandable cross-sectional profile pipes. An example of the isolation of water inflow zones on a well that left the production for three years due to 100% water cut is given, and the dynamics of its operation for 16 years after insulation by two expandable profile packers is shown. Technologies and technical means for regulating oil and water flows in horizontal wells, multi-channel well designs for simultaneous targeted impact and operation of different sections of the reservoir (deposit) are presented. An example is given of the separation of a horizontal well into two segments controllable from the surface and graphs are shown of the dynamics of bottomhole pressures in segments obtained during the well operation. The most promising directions of science development are shown to simplify well designs and improve the quality of their fixation by cardinally solving complications emerged during the drilling process, as well as to increase the productivity of wells by controlling the flow rates of liquids that are extracted from several heterogeneous zones of oil deposits.

Keywords: isolation of water inflow zones, expandable casings, inflow control valves, multi-channel well design, multi-channel lift pipes, well designs, lateral horizontal trunks, profile packers, profile uncoupler, electrical isolator, wireless communication, production rates and water cut of individual areas

DOI: https://doi.org/10.18599/grs.19.3.7

For citation: Abdrakhmanov G.S., Akhmadishin F.F., Muslimov R.Kh., Maksimov D.V., Pronin V.E. Expendable Tubulars and Controlled Oil and Water Withdrawal Increase Oil Fields Profitability. *Georesursy = Georesources.* 2017. V. 19. No. 3. Part 1. Pp. 191-197. DOI: https://doi.org/10.18599/grs.19.3.7

One of the most serious negative factors of the late stage of development in oil deposits is an increase of water cut, which is accompanied not only by a decrease in oil production rates, but also by the occurrence of extensive network of water-saturated channels (reservoirs) between production and injection wells, as well as between aquiferous and oil-bearing interlayers. When drilling wells with horizontal end, the probability of crossing these channels increases, which leads to a rapid flooding of the horizontal trunk.

Well 11251 (Fig. 1) of the Sarapalinsky field was drilled at the end of 1991 into the productive carbonate deposits of the Tournaisian. A year later, the well was flooded to 100%, which led to well decommissioning from production for three years. It took 8 months to find the point of water inflow by geophysical methods and packers (Abdrakhmanov et al., 2003). Then the intervals of water inflow were isolated by two expandable cross-sectional profile packers, and the well was returned to production with an oil production rate of 18-12 tons/day for 16 years (Fig. 2).

Important results for field development were obtained during research and controlled operation of horizontal well 41502g of the Romashkino field (Takhautdinov et al., 2013), drilled in the Bobrikovian horizon and divided into 2 segments using an expandable profile uncoupler (Fig. 3). For 2,5 years of operation of the nearby field, with the highly watered far segment turned off, the accumulated oil production amounted to 12,000 tons, water production – 9,000 tons, and if the horizontal trunk operated along the entire length (i.e. without valves), oil production would be 2 times less, water – 1.7 times more.

On the well 41502g, the dynamics of bottomhole pressures were studied during the operation of two segments simultaneously, and separately – the far and near sections, ***without stopping the operation of the well.***

According to the study, after 15 months of operation (Fig. 4), it can be seen that:

- when the two segments are operated together, the difference in the bottomhole pressure between them is 0.06 MPa;
- when the far segment is operated with the near one turned off, the pressure drop between the segments is 0.25 MPa;
- when the lower valve is choke restricted, the pressure drop is almost the same as for the simultaneous operation of two segments, but the water cut is reduced by 11% and the oil production rate is increased by 1 ton/day.
- with a fully closed lower valve and operation of the near segment, the pressure difference between the sections is 0.75-0.85 MPa, the bottomhole pressure in the near segment decreased by 0.6-0.8 MPa, while the

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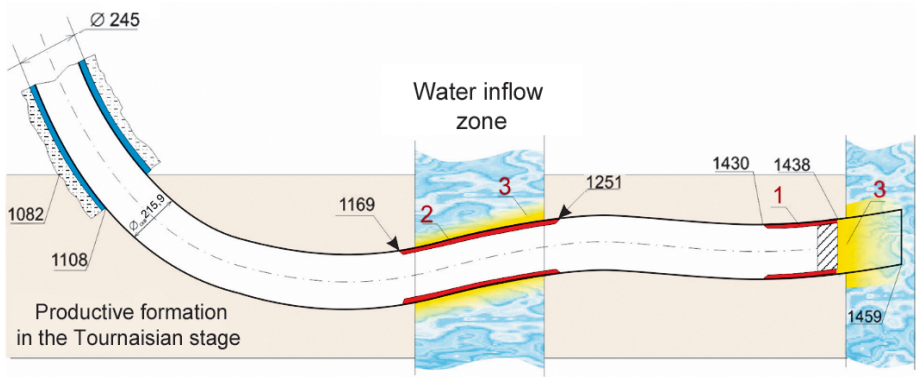

Fig. 1. Isolation of water inflow zones in a horizontal well 11251 with two profile packers of 8 m and 82 m in length

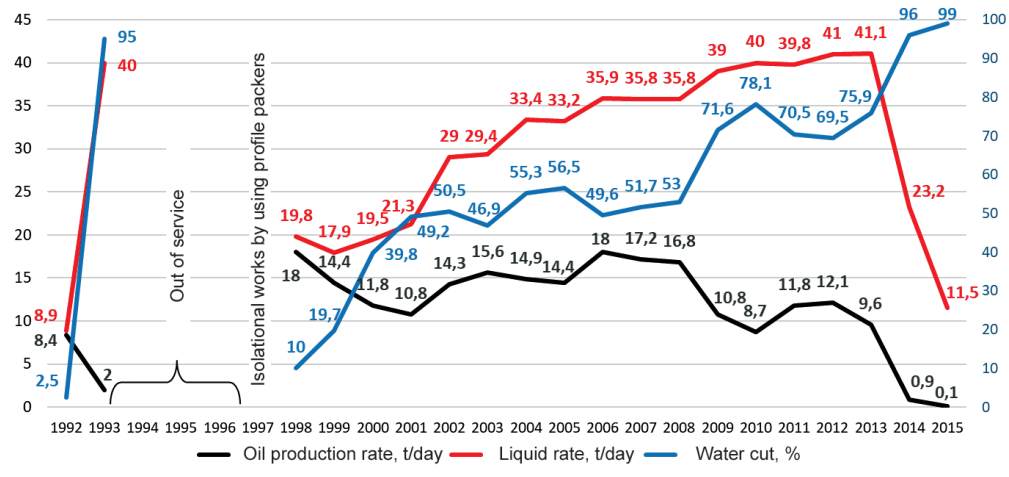

Fig. 2. Dynamics of production rate of well 11251g of the Sarapalinsky field after isolation of the water inflow zones by profile packers

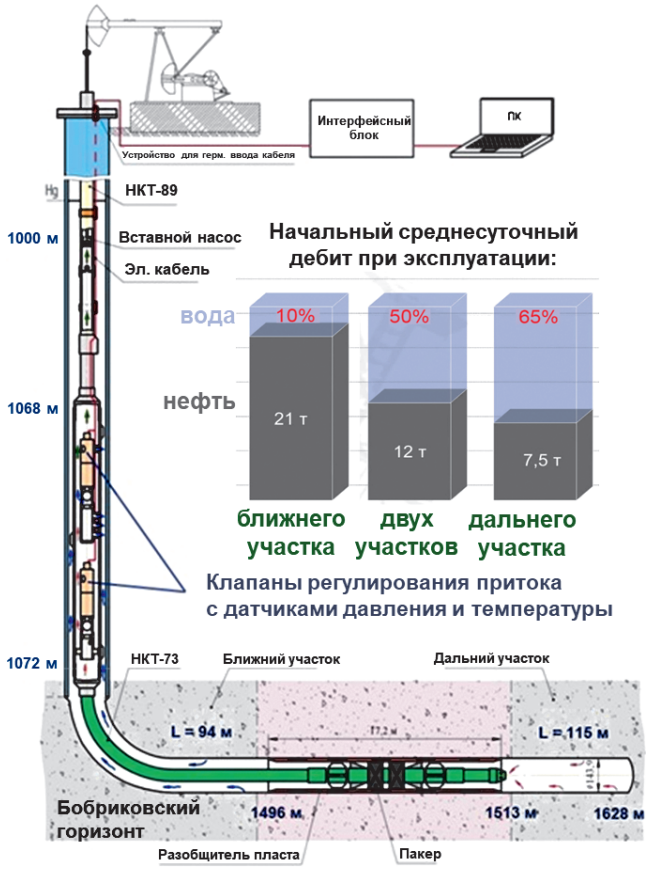

Fig. 3. Schematic location of the equipment for controllable from the surface operation of a horizontal well divided into 2 segments (well 41502g)

water cut decreased by 50 %, and the oil production rate increased by 10 tons/day.

Thus, the disconnection from the production of a highly watered interval allows not only to reduce the volume of produced water, but also to increase the difference between reservoir and bottomhole pressures in other oil-bearing intervals, which substantially increases the oil flow rate of the horizontal well.

Interesting data on the dynamics of bottomhole pressures in this well occur when the injection well is switched on and off (Fig. 5). In spite of the fact that the curve of bottomhole pressure change in the near segment is 7-8 hours ahead of the same graph of the pressure change in the far segment, the difference in bottomhole pressures in the range of 0.73-0.77 MPa between segments of the horizontal trunk is preserved regardless of the increase and decrease in the reservoir pressure. That is, even in the same reservoir in a horizontal well, decompressed intervals, separated by impermeable or low-permeable rocks during separation and targeted impact, work independently with different water cut and different oil rates.

Based on the results obtained for the wells given above, a large number installed in the wells of expandable casing pipes instead of intermediate casing strings (more than 1650 wells), we propose the following ways (italicized in the paper) to develop expandable

Fig. 4. Dynamics of bottomhole pressures and liquid production rates after switching flow regulation valves for well 41502G

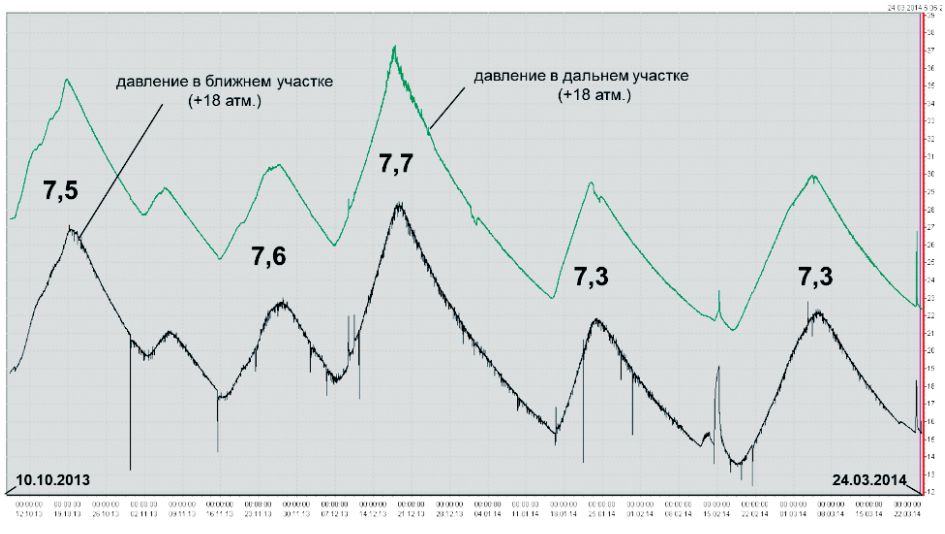

Fig. 5. Effect of cyclic operation of the injection well on the dynamics of bottomhole pressures in well 41502G in the process of oil production from the near segment.

tubulars and technologies for controlled oil and water withdrawal.

Development of technology and technical means for regulating oil and water flows in horizontal wells is shown in Fig. 6.

The specified technology will allow:

1. Withdraw fluid from different segments of the horizontal well and cut out highly watered intervals without interrupting oil production;
2. Apply a cyclic operating method;
3. Increase the current oil recovery factor;
4. Perform continuous monitoring of bottomhole pressure of each site.

Within the framework of this technology it is planned to create:

- cut-offs with wired and wireless communication;
- technology and equipment for installation in a horizontal trunk of any number of uncouplers for a single tripping operation;
- packer elements, triggered on a single technological operation, regardless of their number.

Creation of multi-channel well designs for simultaneous targeted impact and operation of different sections of the reservoir (deposit)

With long-term exploitation of oil fields, when production of small volumes of oil from the reservoirs becomes unprofitable, it is especially important to create special technical and technological solutions to separate and simultaneously operate several inhomogeneous productive zones, opened by one well.

The creation of multi-channel well designs for simultaneous targeted impact and operation of different sections of the reservoir (deposit) will significantly

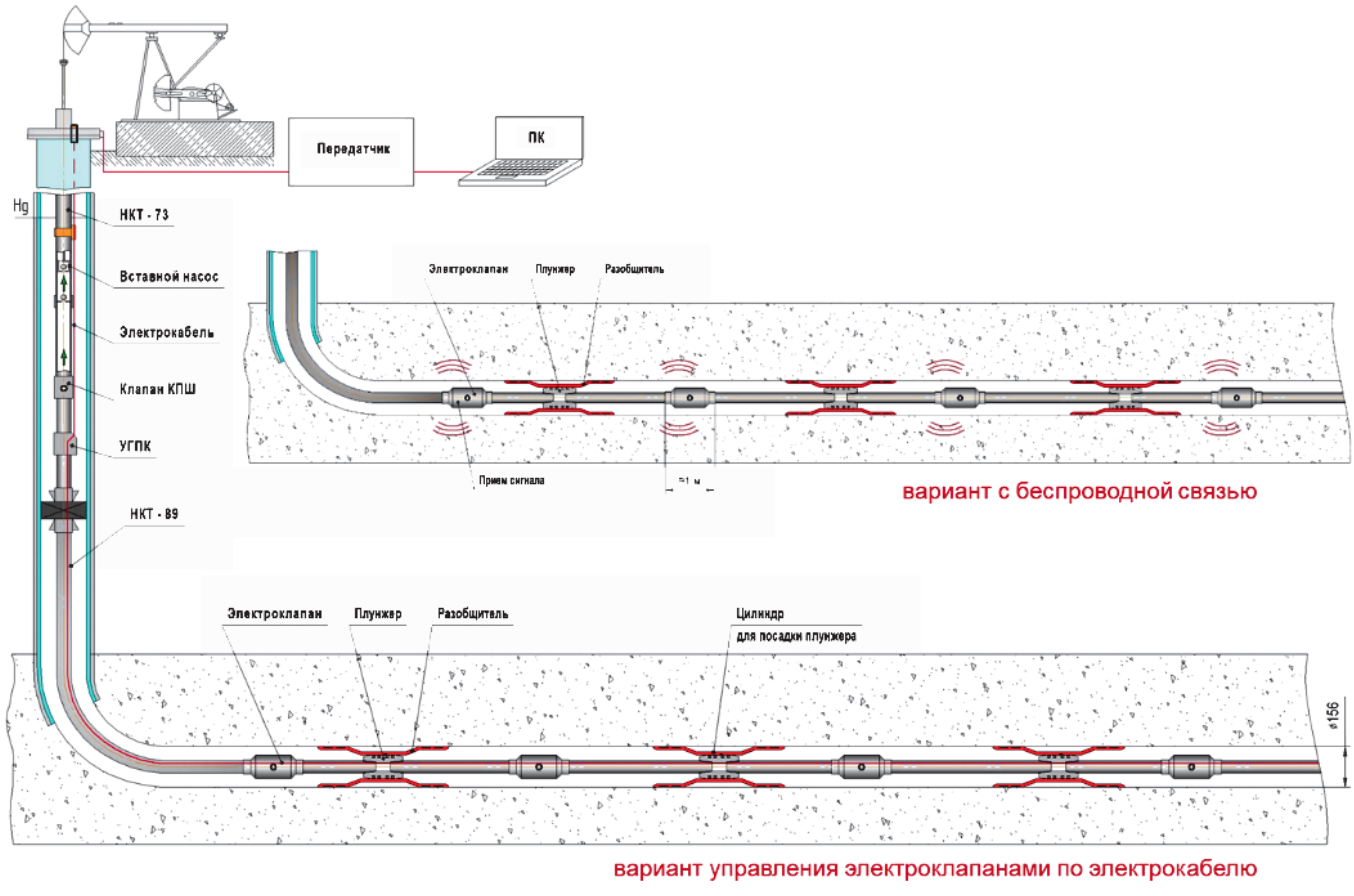

Fig. 6. Layout of the equipment for oil and water flow control in horizontal wells

reduce capital investments in the development of deposits and increase the profitability of oil production.

The technology is based on the separation of the horizontal trunk into segments and the use of multi-channel lift pipes and individual pumps for each segment of a horizontal well, operating from a single hydraulic drive equipped with a flow switch (Fig. 7).

The production rate of the well will be equal to the sum of the production rates of the individual productive intervals. Options of multi-channel lift pipes can be quite different. For example, they can consist of a set of tubes or a six-beam profile pipe sealed between two cylindrical pipes, and also of a package of lightweight hoses. The connection of individual multi-channel pipes is carried out with the help of special multi-channel clutches and

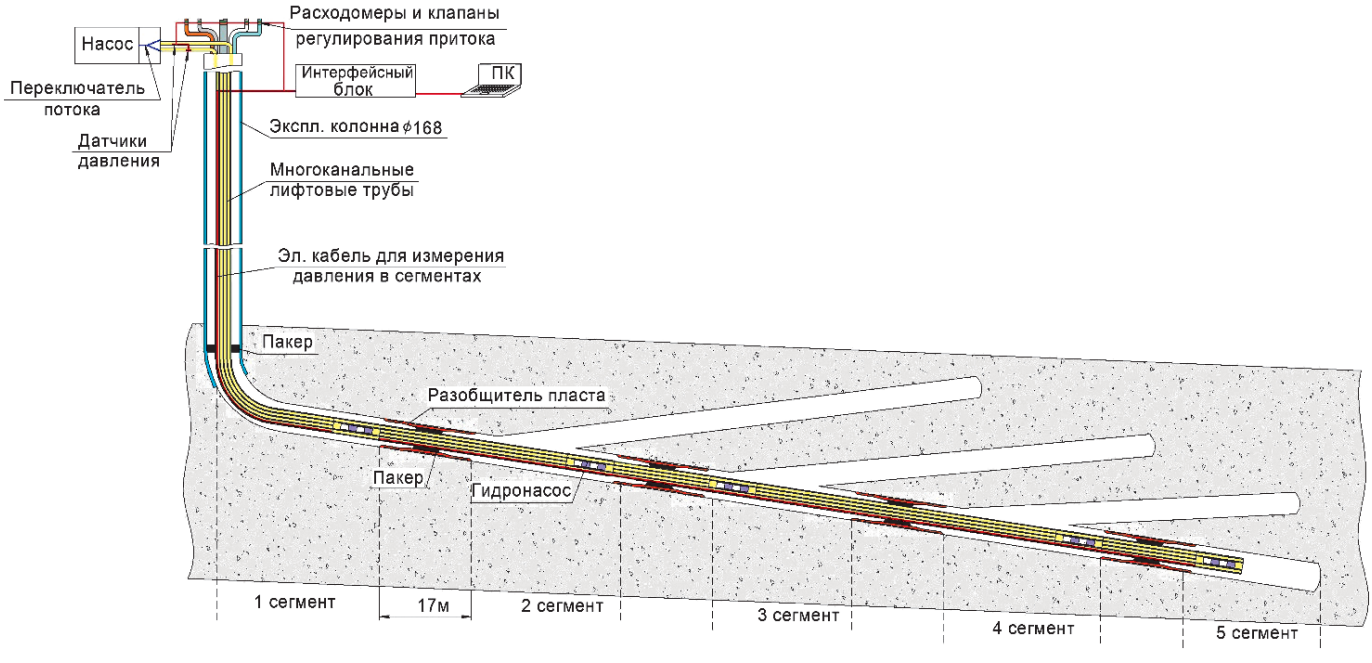

Fig. 7. Schematic diagram of the well designed for simultaneous controlled oil withdrawal from all the trunks of a multihole well

locks, triggered by axial movement of one part of the coupling into the other, i.e. without rotation.

The hydraulic pump consists of a hydraulic drive and a pump part. The capacity of each pump is adjusted from the surface by means of cranes installed at the output of all channels. Pumps operate independently from each other. By switching the flow direction of fluid in the pump installed at the wellhead, a constant computed fluid withdrawal takes place from each interval.

An even greater effect can be obtained from the application of this technology in multi-trunk wells.

The advantages of this method allow to:

1. Increase the production rate of oil by simultaneously withdrawing fluid from each trunk of multihole well or each segment of horizontal well using separate pumps.

2. Continuing the operation process, reduce the water cut of the production and conduct the bottomhole treatment in the required intervals.

3. Manage the profile of oil inflow in the zone of the horizontal trunk, due to differentiated effects on different **intervals** of the reservoir.

This method is being developed for the first time in the international practice of well construction and will be of great interest not only for Russian but also for foreign oil companies.

The creation of such equipment will be the beginning of a new more rational approach to the development of oil fields – with the exception of withdrawal of huge water amounts, with simultaneous increase in the oil recovery factor and a significant reduction in its cost.

Simplification of well designs with a simultaneous increase in the quality of fastening

To ensure work safety and environmental protection in the process of drilling and operation of wells, all intervals with different reservoir pressures, rock falls and shedding should be covered by casing pipes. However, in complex mining and geological conditions, the well crosses a large number of such formations, and the worldwide fastening technology with telescopic arrangement of intermediate casing strings does not always allow meeting these requirements.

For example, in a foreign reference book of an oil engineer (Spravochnik inzhenera-neftyanika ... [Guide book of an oil engineer], 2014), one of the options of the conventional design of a deep well is given (Fig. 8, a), which provides for the separation of formations by ten casing strings with a ratio of diameters at the beginning and end of drilling 10:1. Seven of them are intended for overlapping of multi-pressure strata and landslide zones. In the process of drilling, such a telescopic structure cannot be changed and if additional complications arise, the well will need to be re-drilled, providing additional intermediate casing strings.

No.	Length of profile packers, m	Time required for their installation, hours	
1	128,6	58	Installation of six profile packers using punches with simultaneous drilling and expansion - 9.5 days
2	157	48	
3	88	37	
4	140	34	
5	51,5	28	
6	70,6	22	
7	120	264	Installation of profile packers with additional expansion and dispensing of expanders - 11 days

Table 1. Data on the length of profile packers and the time required for their installation in well 18

Drilling of well 18 was carried out in the particularly difficult mining and geological conditions of the Aleksandrovsky field of JSC Tatneft-Samara, using ten casing strings, including seven columns of expandable profile pipes to block the absorption zones of the drilling mud and rock falls under the patent of Tatneft PJSC (Fig. 8, b). In this case, the sixth string is installed over five casing strings already installed in the well, as the hope of isolating this zone by the filler overwash was not justified, that is, the technology of local fastening of wells allows changing the design even during drilling. The table gives data on the length of profile packers and the time required for their installation in well 18. Thus, even in difficult mining and geological conditions, a well can be built on a schedule without complications with significant savings in casing, cement and time. That is why the technology of local fastening of the well walls by expandable pipes has gained worldwide recognition.

A big impact on the world economy is the drilling of wells offshore, which is a global multi-billion dollar business with great prospects. The offshore drilling challenges a difficult task – to ensure the profitability of all production processes, while fulfilling strict requirements for safety and environmental protection.

All this is mainly related to well designs (Fig. 9). According to conventional designs, the deeper the well, the longer intervals it takes to drill without casing, and the higher the likelihood of complications. In addition, many problems in the process of exploitation are closely related to the complications in drilling. For example, inter-casing flows or cement stone of a poor quality behind the casing in the intervals of large caverns and others.

Therefore, when developing deep-water productive deposits, the quality and timeliness of fastening wells during drilling significantly affects the economy and profitability of the project.

Fastening wells with expandable tubulars fundamentally solves this problem in combination with

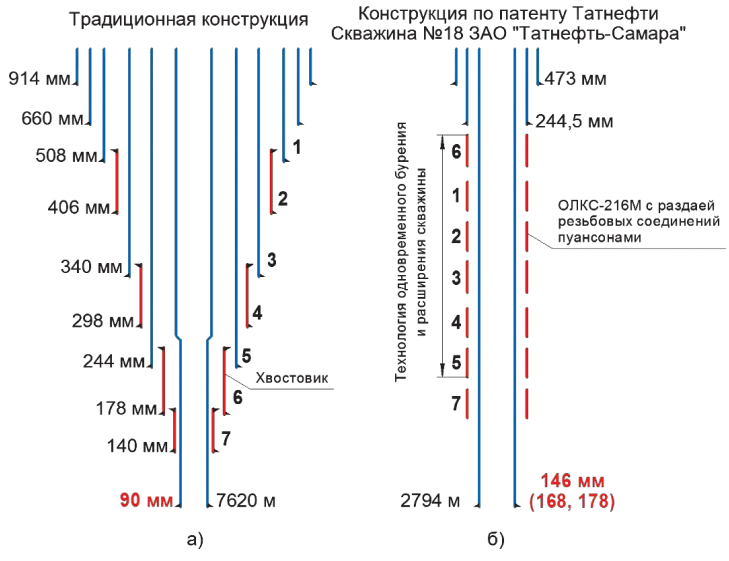

Fig. 8. Designs of oil and gas wells crossing a large number of formations requiring overlapping by casing pipes during drilling. OLKS-216M – the modernized equipment for local fastening of well walls with a diameter of 215.9 mm

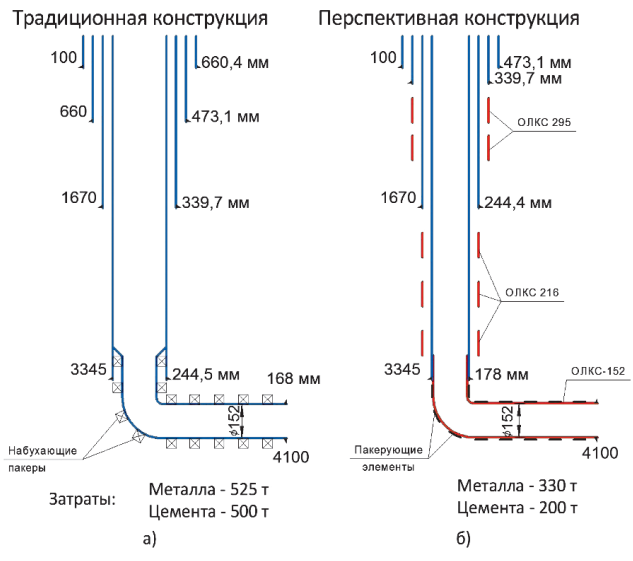

Fig. 9. Examples of offshore structures: The conventional design is the construction of wells with the elimination of complications by pumping plugging material into the well; a promising design is the construction of wells with the use of expandable tubulars

intermediate casing strings, which will only be used in the presence of high pressure formations.

A perspective diagram of offshore well designs shows the possibility of drilling according to the schedule without complications. All the zones of absorption of drilling mud, shedding and rock falls are overlapped immediately after opening. At the same time drilling in these intervals is conducted with simultaneous expansion of the wellbore and logging.

The advantage of this design is the ability to overlap by casing pipes of all multi-pressure formations and landslide zones with simultaneous reduction of metal and cement costs and an increase in the quality of fastening of intermediate and production columns.

Expandable tubular technologies of Tatneft PJSC are currently applicable in the development of such a project for any oil and gas producing company first on experimental wells and then on a large scale.

Conclusions

1. The operation of multi-segment and multi-hole wells controllable from the surface makes it possible to increase the oil recovery factor and to substantially limit the inflow of water from the reservoirs.

2. The use of multi-channel lift pipes and individual hydraulic pumps for simultaneous oil production from heterogeneous sections of deposits will lead to a significant reduction in capital investments in the development of oil fields.

3. Experience in the use of profile packers shows that one of the most promising areas of development of science and practice in the field of well construction is the concept of drilling with a simultaneous increase in the diameter of the trunk and subsequent overlap with expandable tubulars of all zones of possible complications immediately after their opening, except formations with anomalously high pressure, which are overlapped by intermediate casing strings.

Such a technology, apart from the elimination of many complications and accidents in the drilling process, will bring significant revenue in the development of oil and gas fields due to improved quality of fastening wells, and hence the period of their maintenance-free operation.

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Manuscript received 6 July 2017;
Accepted 27 July 2017;
Published 30 August 2017