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Comparison of Various Tracer-Based Production Logging Technologies Application Results in One Well

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Abstract

In recent years, oil and gas producing companies have increasingly migrated towards using tracer-based methods to obtain data on horizontal wells operation. The interest in these technologies is largely due to their ability to obtain data over a long period of time with a radical decrease in the required resources, thereby providing new opportunities for well management and increasing cumulative production. The aim of this article is to compare the results of applying different tracer-based systems in one well.

Tracer-based technologies produced by different manufacturers vary in physical principles of operation, as well as in the methods of their injection into the well or reservoir. Tracers designed for long-term work are injected into the reservoir with marked proppant or lowered into the wells in the lower completion cassettes. For the first time, alternative tracer-based systems were applied in one well, ensuring the selectivity of work with oil and water. This allowed us to compare the results and evaluate the technology's advantages and disadvantages. The well was completed by multi-stage hydraulic fracturing with the possibility of subsequent port control using coiled tubing. Each of five well intervals were equipped with two tracer cartridges fixed on an MFrac sleeve on both sides. In addition, proppant with markers was pumped in 3 months. The unique signature of the marker was used for each fracturing stage (5 unique signatures for each of 5 fracturing stages).

As a result of this world-first field application of alternative tracer-based systems, valuable analytical material was obtained related to the quantitative analysis of various tracers, the performance of different polymers, and the stability of the tracers' allocation in the formation fluid. The data obtained confirmed the character of the marked proppant pack washing out with the formation fluid in comparison with the tracer casings attached to MFrac port on both sides.

The following results were achieved upon completion: additional tools were obtained for the correlation of data on the tracers amount and concentration, and comparative indicators of different tracer technologies in terms of efficiency and work accuracy were identified. It was also confirmed that the marked proppant is not washed out into the well under these reservoir conditions. The authors of this article were the first to compare the technologies with different approaches to the tracers' placement in a well within one project.

Based on the project results, the obtained data allowed us to answer many pressing questions from oil and gas producing companies related to the comparison of tracer systems.

Introduction

In today's conditions of active development of drilling technologies, well completion and production intensification, there is a trend towards the growth of the length of horizontal sections and, as a consequence, an increase of the hydraulic fracturing stages (Rudnitsky, 2017). At the same time, there is an emerging trend both in Russia and abroad of using various tracer-based study methods to obtain data on the horizontal well intervals operation. The main advantage of these technologies is the ability to obtain data over a long period of time with a significant decrease in the required resources, thus providing new opportunities for well and reservoir management and increasing the cumulative production.

Tracer-based production logging technologies involve the placement of flow indicators along the horizontal well. When they come into contact with the target formation fluid (oil, water, gas), the tracer particles are injected and move along with the flow. Fluid samples are taken from the wellhead and analyzed in order to identify the number of tracers of each code. Data on the oil and water inflow distribution over each interval are interpreted based on the test results.

According to the method of tracer placement into the well (reservoir), tracer technologies can be classified as follows (Dulkarnaev, Ovchinnikov, Gurianov, Anopov, Malyavko, 2018):

1. Application in the composition of the liner configurations during well completion (downhole casings, filters of special design, cassettes).
2. Marker cassettes, launched into operating wells. Anchoring of the cassettes is carried out with the help of downhole operations with the application of coiled-tubing systems or tubing with a workover rig.
3. Application of marked polymer-coated proppant for multi-stage hydraulic fracturing
4. Injection of tracers with fluid (hydraulic fracturing fluid, acid solutions)

One objective of the present article is to compare the efficiency of two independent tracer-based technologies based on their application in one horizontal well:

1. Production logging system using downhole cassettes;
2. Production logging system using marked proppant.

The System of Tracer-Based Production Logging Along the Horizontal Well Using Downhole Cassettes

This production logging system is based on the placement of tracers in special downhole cassettes (cartridges) that are fixed in the lower completion (Figure 1).

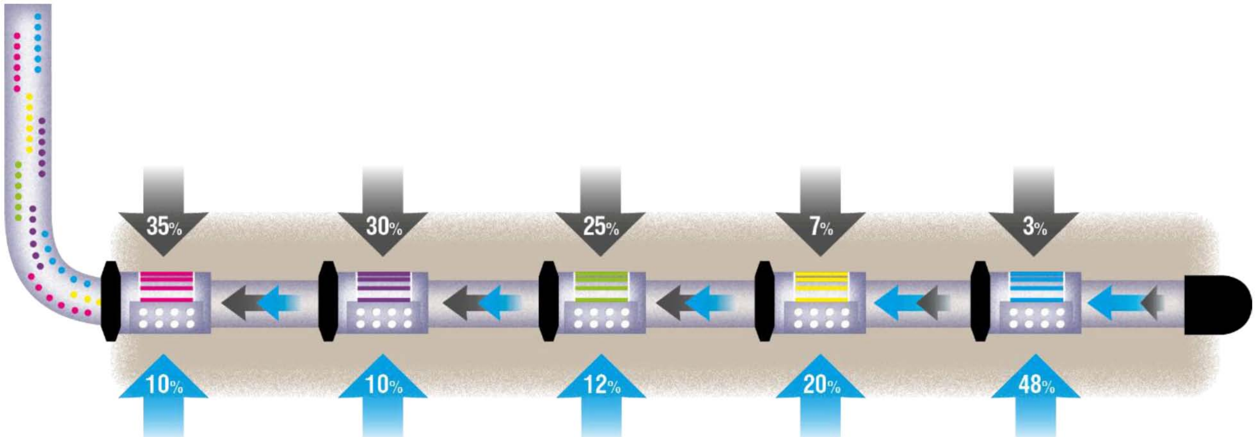

Figure 1—The system of tracer-based production logging along the horizontal well using downhole cassettes.

The layout of the downhole cassettes is presented in Figure 2.

Figure 2—Downhole Cassettes with Tracer-Based Material

Marked, granulated material was used as a tracer material. This is a nonhomogeneous microfilled composite material into which quantum marker-reporters are added, serving as inflow indicators and performing horizontal well monitoring for long periods of time (not less than 5 years).

Marked granulated material combines various functions (Figure 3):

1. Frame – ensures strength properties to prevent the destruction or change of the polymer particles geometric dimensions
2. Filler –by dissolving upon contact with water or oil creates hydrophilic and oleophilic diffusion channels through which movement of marker-reporters from the internal part of the polymer to its surface occurs
3. Quantum marker-reporters – precisely indicate oil and water inflow

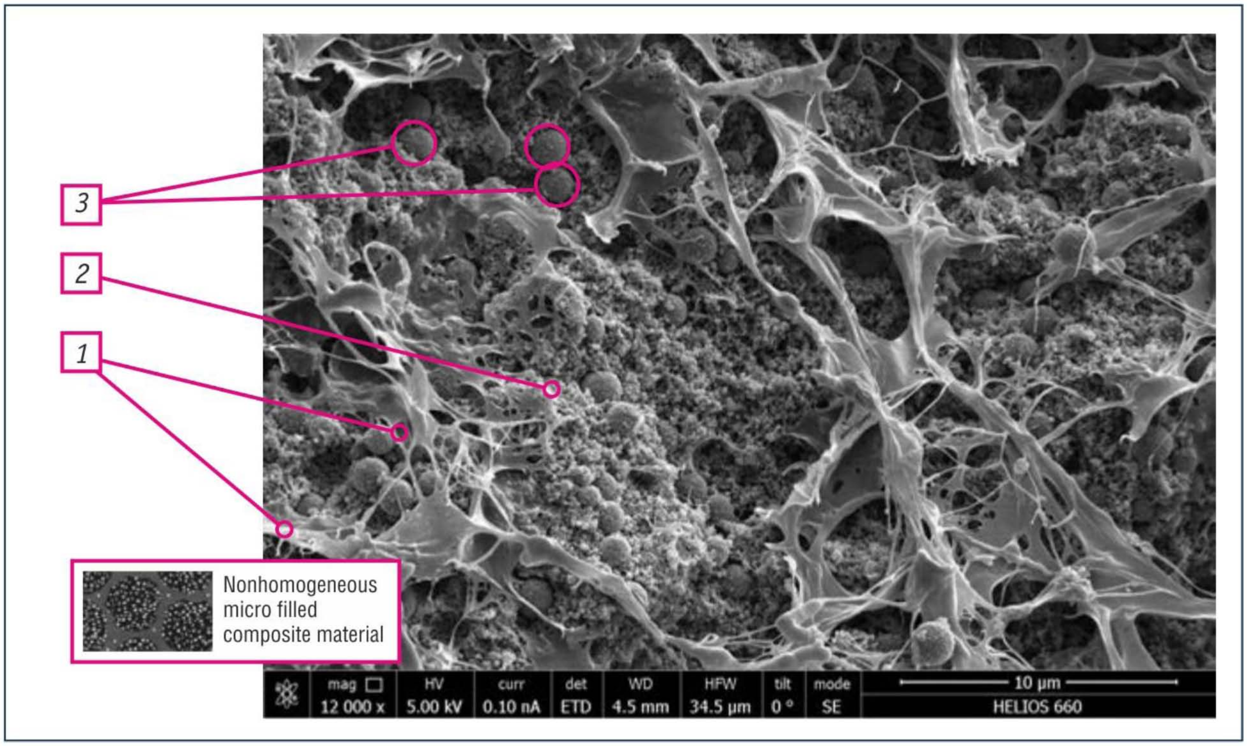

Figure 3—Nonhomogeneous micro filled composite material with quantum marker-reporters in the scanning electronic microscope: 1 – Frame; 2 – Filler; 3 – Quantum marker-reporters

Therefore, the marked granulated material is a cross-linked polymer matrix that enables the injection of quantum marker-reporters into the formation fluid with a steady concentration and duration, thereby facilitating long-term monitoring.

Bench Tests of Cassettes for Resistance to External Mechanical Loads

Additional bench tests were conducted to check the stability of the cassettes when exposed to external mechanical loads, including a turning moment of 20 kN * m to simulate jamming during descent. These tests were carried out on a prototype cassette mounted on the pipe. The filtration part of the cassette was welded to the supporting rings. Further on, the cassette with rings was fixed to the pipe with the help of 16 adjusting screws through each of the rings, with a tightening torque of 45 N * m. The sample cassette was installed on the hydraulic key; on one side it was fixed with the cassette, and on the other side – with the pipe. Opposite marks were put on the cassette and pipe for visual control of the absence of twisting. Next, the cassette was subjected to a rotating force of 20 kN.

Once the test was completed, a visual inspection for defects identification was conducted. The marks displacement was not observed during the tests. There were no traces of screws turning or failing after the cassette disassembly (Figure 4).

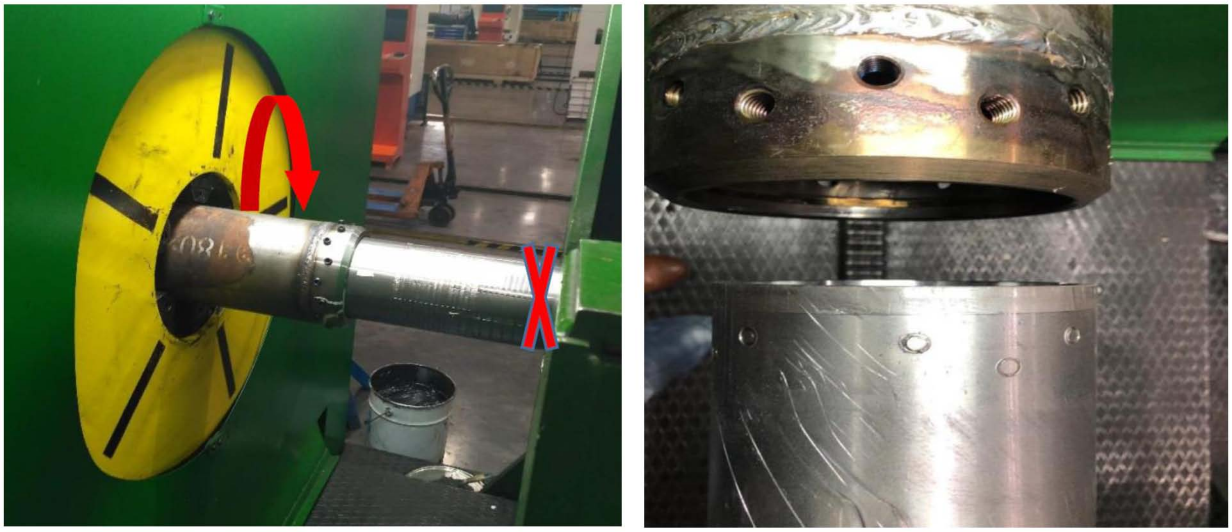

Figure 4—Jamming tests for resistance to external mechanical loads.

Lower Completion

The 5-interval horizontal well No. 6303g of the Kochevskoye field was selected as a candidate well. During the study, 10 downhole cassettes with tracer material were used, with 2 cassettes used for 1 interval. The cassettes had a wire-type filter element manufactured according to AISI-304 standard. Calculations were made for lowering the shank to determine the reliability of the selected frames. During the calculations, the possibility of lowering a 114 mm shank to the depth of 3704 m with multi-stage hydraulic fracturing completion was considered: 5 hydraulic fracturing sleeves, 5 hydromechanical packers, and 10 downhole cassettes (mounted above and below the hydraulic fracturing ports).

Special software was used to build the profile and complete engineering calculations. According to the calculation results, no sinusoidal and spiral bending of the transport column was revealed during the lower completion to the depth 3704 m subject to the planned well survey. The cassettes were placed on the blind part of the shank at 114.3 mm, in close proximity to the MFrac port to ensure maximum contact of the marked granulated material with the formation fluid. The cassettes were assembled in accordance with the technical requirements of the oil producing company and the manufacturer of the tracer-based monitoring system. The layout of the downhole cassettes is presented in Figure 5.

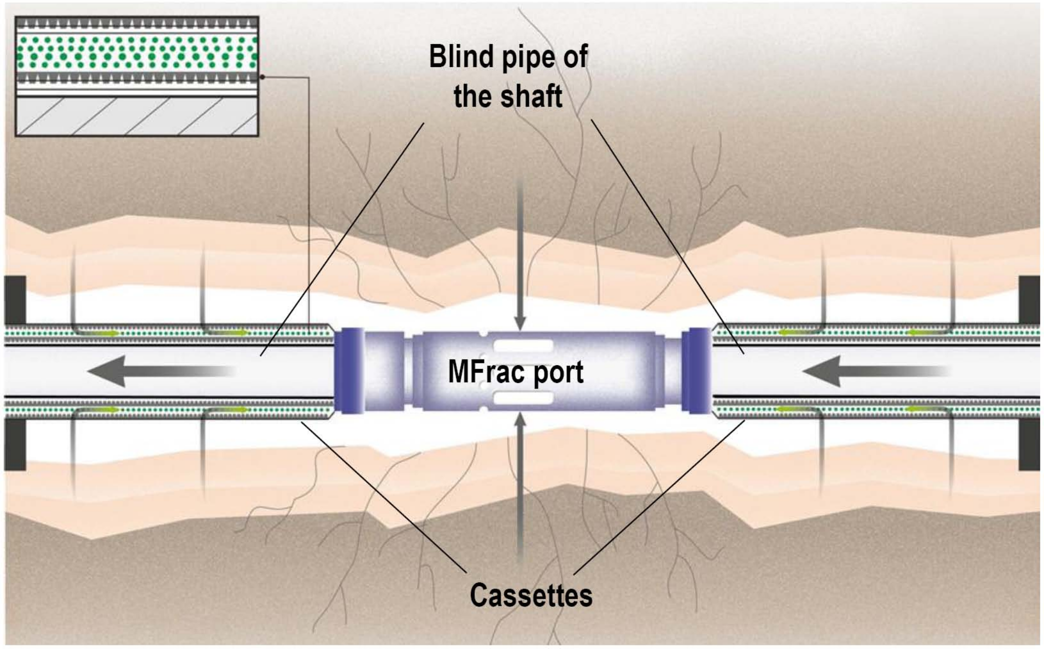

Figure 5—The layout of the downhole cassettes in close proximity to MFrac port (2 cassettes per 1 interval).

The lower completion proceeded without complications or incidents, and the above-mentioned tracer-based monitoring system was installed in the regular mode.

The System of Tracer-Based Horizontal Well Production Logging with the Application of Marked Proppant

After lower completion, the well was stimulated with multi-stage hydraulic fracturing using the second tracer-based monitoring system – marked proppant. This technology involves marker monitoring using marker-reporters made of quantum dots that are placed in the proppant polymer shell (Figures 6, 7).

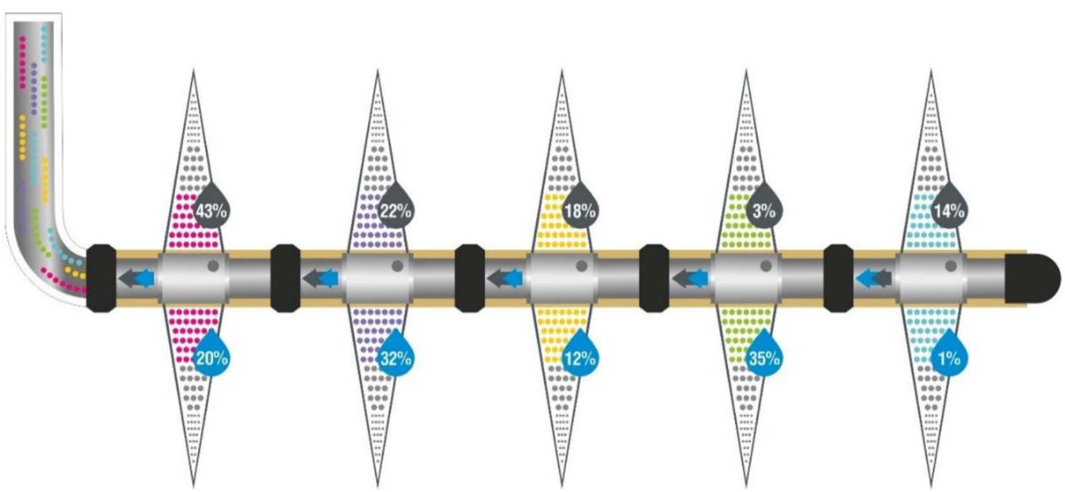

Figure 6—System of tracer-based horizontal well production logging with the application of marked proppant

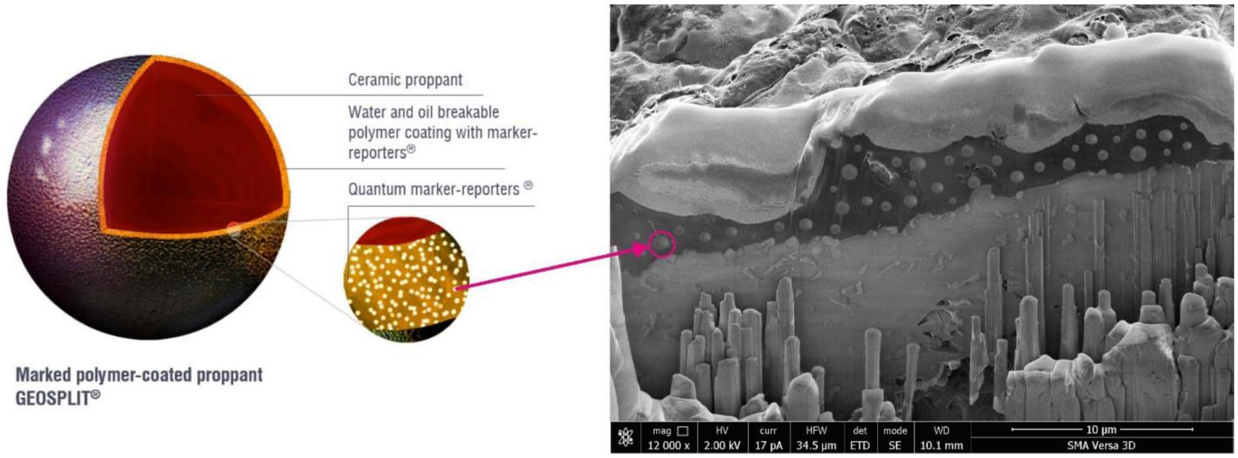

Figure 7—Grain of the Marked Proppant

The polymer shell of the proppant has a thickness of 15 microns and degrades during the continuous contact with the target fluid. Marked proppant has two types of coatings – oleophilic and hydrophilic. From Figure 8 it is clearly seen that the oleophilic proppant is not wetted with water, unlike the hydrophilic proppant. Therefore, the oleophilic proppant injects markers only in oil, and hydrophilic only in water (Figure 8).

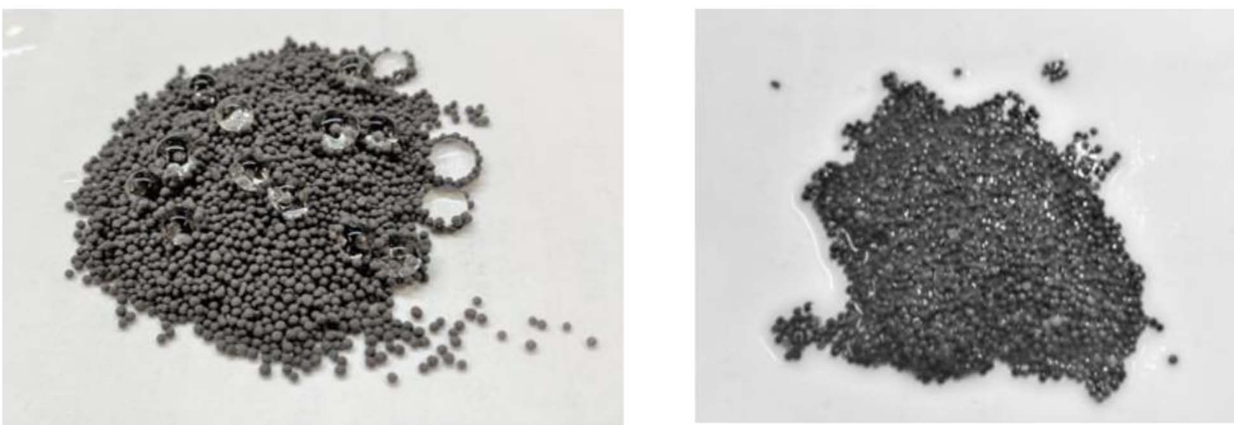

Figure 8—Oleophilic (left) and Hydrophilic (right) Marked Proppant

During the multi-stage hydraulic fracturing of well 6303g, the marked proppant with 5 signatures was injected with the last proppant pack in the volume 15 tons at each stage, while the proppant marker codes did not match the downhole cassette marker codes. Thus, 2 independent tracer-based systems were placed in one well (Table 1).

Table 1—Signatures (codes) of markers injected into well 6303g

zone №	Interval (place of MFrac ports installation), m	Number of cassette signature	Number of proppant signature
1	3585,06-3585,71	1	10
2	3500,94- 3501,59	2	7
3	3415,25-3415,90	3	14
4	3317,39-3318,04	8	6
5	3222,45-3223,10	9	5

Complete Cycle

The complete cycle was as follows (Figure 9):

1. Synthesis of marker-reporters;
2. Injection of markers in the well;
3. Collecting fluid samples from the wellhead;
4. Receiving and interpreting data;
5. Analysis of the information.

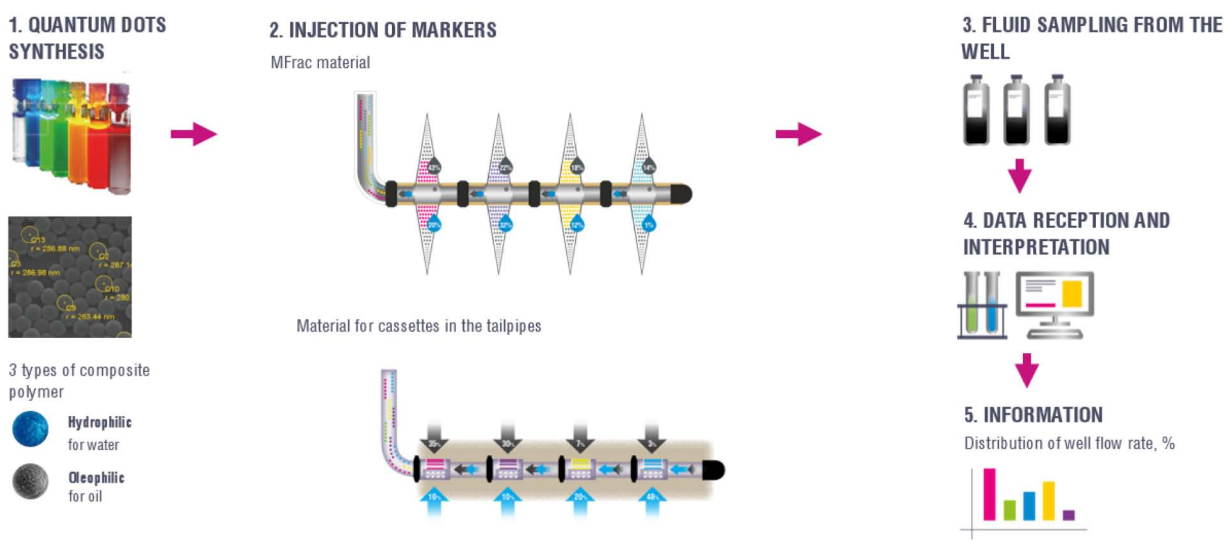

Figure 9—Complete Cycle of Works

Production logging was performed by taking formation fluid samples from the wellhead. These samples were analyzed with the hardware-software complex utilizing flow cytometry (Gurianov, Katashov, Ovchinnikov, 2017). This method is based on the item-by-item study of the dispersed phase elements using light scattering signals and allows for determining the quantitative distribution of "hydrophilic" and "oleophilic" markers of each code with a high accuracy.

Results of a Comparative Analysis of Various Tracer-Based Systems

The results of the productive intervals dynamics for the cassette solution are shown in Figure 10. Figure 11 displays the results for the marked proppant solution.

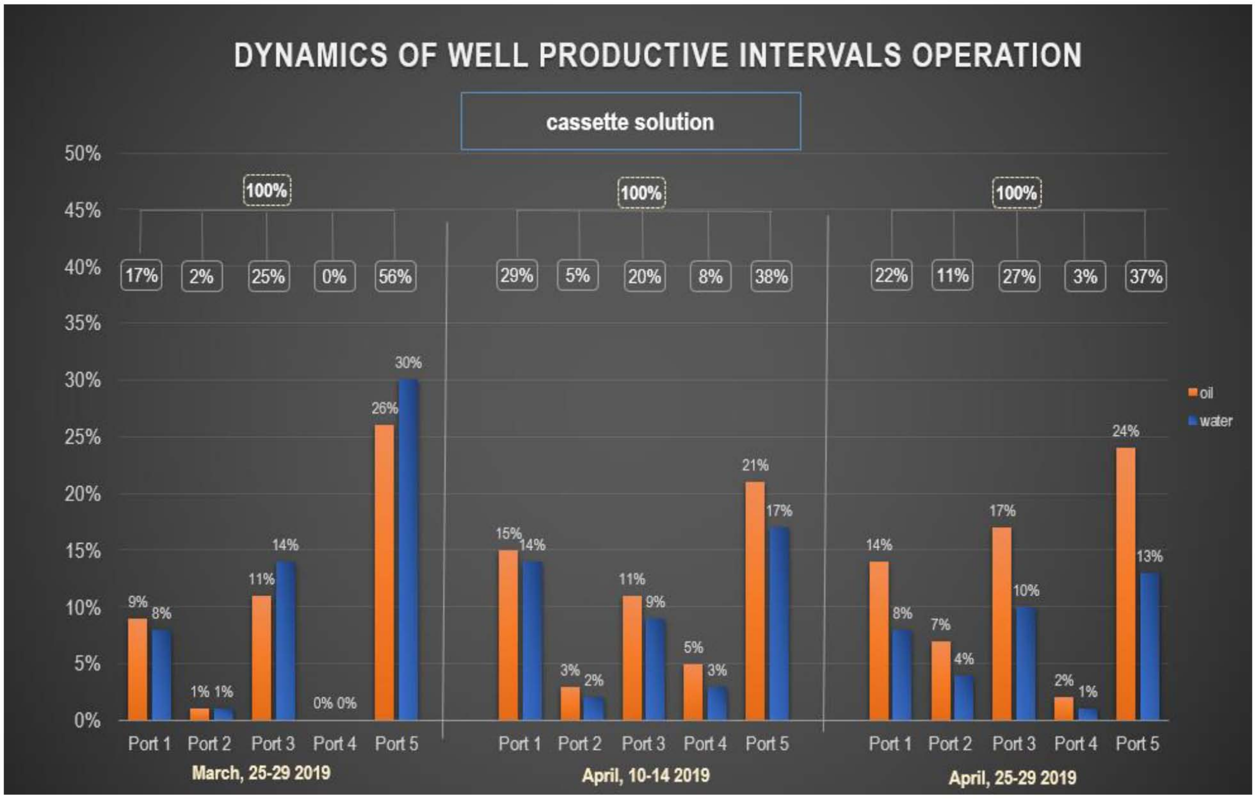

Figure 10—Dynamics of well 6303g intervals operation (cassette solution)

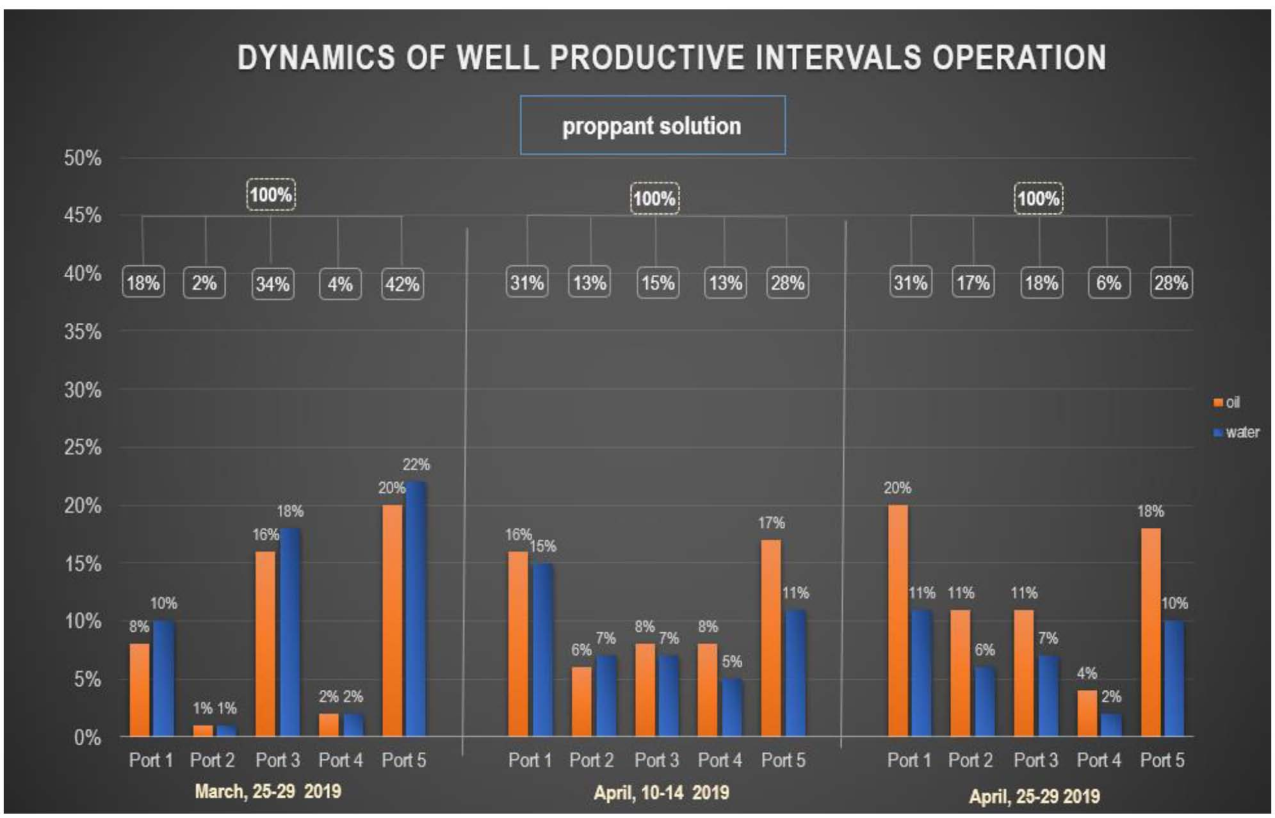

Figure 11—Dynamics of well 6303g intervals operation (proppant solution).

According to the analysis of the results, a steady convergence of the tracer-based systems was established (Table 2).

Table 2—Comparative analysis of two tracer-based systems monitoring data

№	Dates of logging operations	Mean value of the divergence in oil,%	Mean value of the divergence in water,%
1	February, 24-28 2019	0,8	8,0
2	March,10-14 2019	2,8	3,6
3	March, 25-29 2019	4,4	5,2

At the same time, there was some discrepancy between the comparative results of the proppant and cassette solutions during the interpretation of the productive water intervals contribution that was noted during the early stages of the tests. Presumably, this discrepancy is due to the following: the marked material of the cassette is in the well prior to the beginning of the multi-stage hydraulic fracturing. Therefore, it is possible for multiple contact with completion fluid as well as with the fluid used during multi-stage hydraulic fracturing (pressure test, mini hydraulic fracturing, hydraulic fracturing) to occur. These factors may cause distortion in determining the actual productive interval inflow. This discrepancy in water is reduced after processing working fluids. Once the well starts operating in the regular mode, both systems demonstrate low indicators of the Port 2 and Port 4 contribution to the total well flow rate. Based on the obtained data, we confirm the nature of the marked proppant pack washing with the formation fluid in comparison with the cassettes fixed on both sides of the MFrac ports.

Conclusion

As a result of the world's first field application of alternative tracer-based systems, analytical material was obtained on the quantitative analysis of various tracers, the efficiency of polymers, and the stability of tracers' injection into the formation fluid. This experimental data confirmed the character of the marked proppant pack washing with formation fluid in comparison with the tracer casings fixed on both sides of MFrac ports.

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