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Implementation of Tracer-Based Production Logging Technology for 3 Phases Inflow Profiling in Offshore Extended Reach Drilled Wells

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Abstract

In the context of high hydrocarbon price volatility on the global market and worsening resource structure an increasingly greater attention is paid to the search of effective and economically sound tools for production and exploitation process management and control, including in horizontal and directional wells.

Traditional approaches to horizontal well surveys by PLT using CT come with low industrial safety of work performance, high cost and, therefore, limitation in wide use. One of the alternative approaches is to use well marker monitoring system enabling to obtain unlimited information about inflow profile and composition along a horizontal well without interventions on a long-term basis.

This paper describes an approach of placing the marker monitoring systems as a part of completions and carrying out 3-phase monitoring for oil, water and gas, including off-shore project conditions.

Introduction

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This paper describes an approach of placing the marker monitoring systems as a part of completions and carrying out 3-phase monitoring for oil, water and gas, including off-shore project conditions.

General Description of 3-phase Monitoring Layout Solution, Cassette Design

The technology of horizontal well marker tests consists of one-time placement of high-precision indicators of a fluid inflow and following monitoring of horizontal well performance during 5+ years. Horizontal well marking can be done by several alternative ways, including the use of marker cassettes inserted as a part of the downhole completion assembly, or markers directly integrated into an inflow control device design (Figure 1).

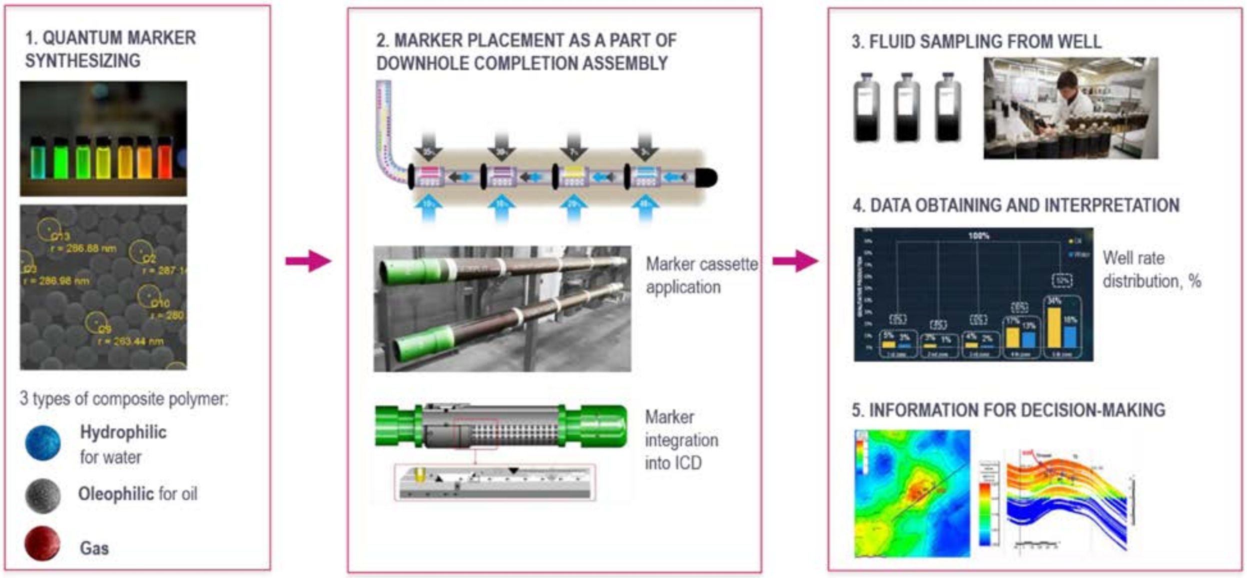

Figure 1—Well marker diagnostics and monitoring technology

After well de-commissioning fluid samples are taken at the well-head that being analyzed in a lab for a quantity distribution of markers of each code. Then the data is translated into gas, water and oil rate distribution by intervals.

Marker cassette testing

Before initiating any project each cassette structure is subject to acceptance test procedure for external mechanical impact resistance:

- external torque test simulating pipe jamming when rotating during landing.
- longitudinal displacement test simulating pipe sticking.

The Figures 2–3 show a process of testing of marker cassette prototype model with external diameter of 178 mm mounted on a branch pipe with external diameter of 140 mm. The cassette was attached to a pipe body using standard locking screws with a torque of 45 Nm. The test was carried out on a special stand with a hydraulic tong.

Figure 2—Marker cassette prototype model installation on a branch pipe of a well casing

Figure 3—The process of marker cassette prototype model testing on a stand with hydraulic tongs.

The marker cassette prototype model was mounted on a hydraulic tong attached to the body from one side and to the branch pipe from another. The cassette and the branch pipe had opposed marks for visual slip control. Then an external forced torque was applied to the cassette that was constantly recorded during the testing (Figure 4).

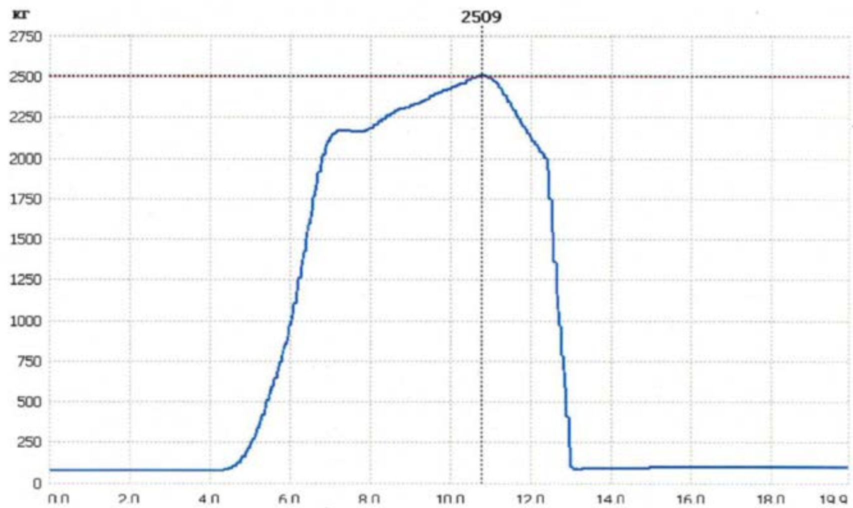

Figure 4—External torque records during the tests

Upon test completion visual and flaw-detective inspection was carried out. No displacement of the marks and slip traces were found during the test. The cassette design proved preservation of integrity and slip-free at maximum torque of 25.09 kNm that conformed with clients' target values.

New Approach to Well Marking

Broad coding capacity of the quantum marker-reporters used as oil, water and gas inflow indicators (63 codes) gives the opportunity to improve information content of the data obtained significantly through marking each marker cassette or ICD with a unique code. Therefore a possibility to obtain inflow profile both within horizontal well and by each cassette or ICD within the limits of one interval emerges.

The following will be the one of such examples.

The Smart ICD with Packer Monitoring System

This solution assumes equipping each inflow control device with a set of marker indicators of unique signatures enabling to obtain inflow profile in numerical terms with unique identification of a source of water breakthrough (specific ICD).

In addition the system can be equipped with marker cassettes that are installed on the left and right sides of each straddle parker to monitor its sealness (Figure 5). In case of packer leak the markers of proper signature will be found in the well fluid samples.

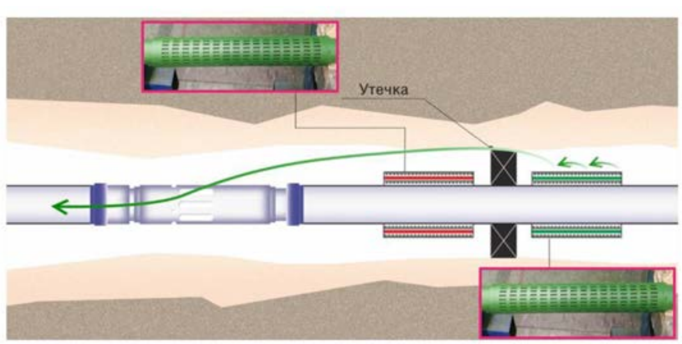

Figure 5—Straddle parker sealing monitoring system in the horizontal well

The Figure 6 shows an example of 3-interval horizontal well marker diagnostics using ICD marked by unique signature of markers and packer sealing monitoring system:

- Hydrophilic matrix - to identify water breakthrough;
- Gas matrix – to monitor gas inflow profile;
- Oleophilic matrix – evaluation of bottom-hole treatment of residual hydrocarbon-based mud (at initial stage of testing) and inflow profile monitoring for hydrocarbon fluid.

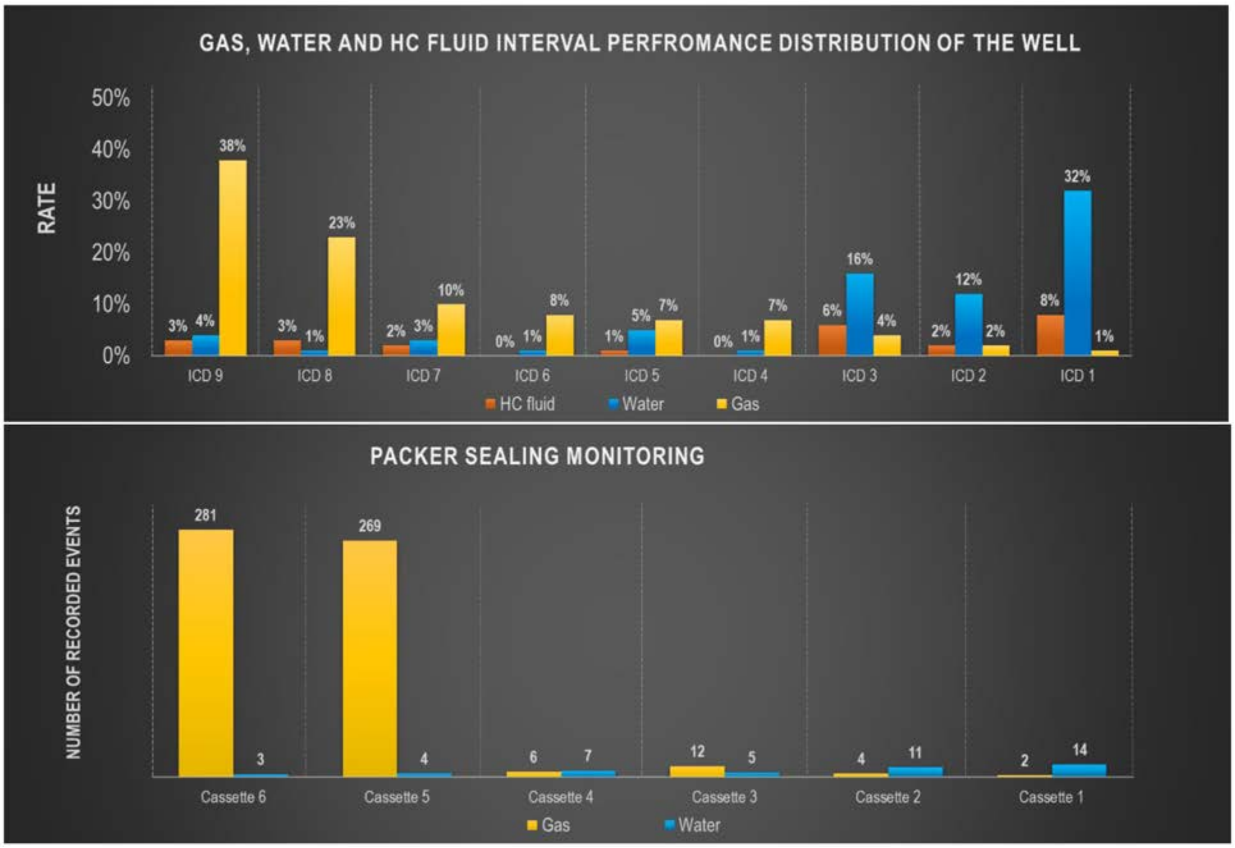

Figure 6—The results of horizontal well marker diagnostics with 3 intervals with numerical identification:
- **inflow profile by each ICD (HC, water, gas)**
- **migrations and saddler packer sealing evaluation (gas, water)**

As the marker diagnostics results show water inflow through ICDs No 1, 2, 3 and gas migration through packer No 3 have been identified. The test results demonstrate higher information content with opportunity of selective control of each ICD as compared to traditional approaches.

Sampling technology for 3-phase monitoring without change in existing piping

The experience in application of the marker diagnostics in off-shore projects demonstrates the necessity of use of technological solutions in sampling that explicitly contains no external interventions in existing well connections and pipeline infrastructure.

If the formation fluid samples are taken through a sampling cock as a standard procedure, the gas markers sampling in a 3-phase gas liquid mixture flow required a new approach to be developed.

The Figure 7 shows a process flow chart of the developed gas marker sampler used in one of the fields. The device exterior is shown on the Figure 8.

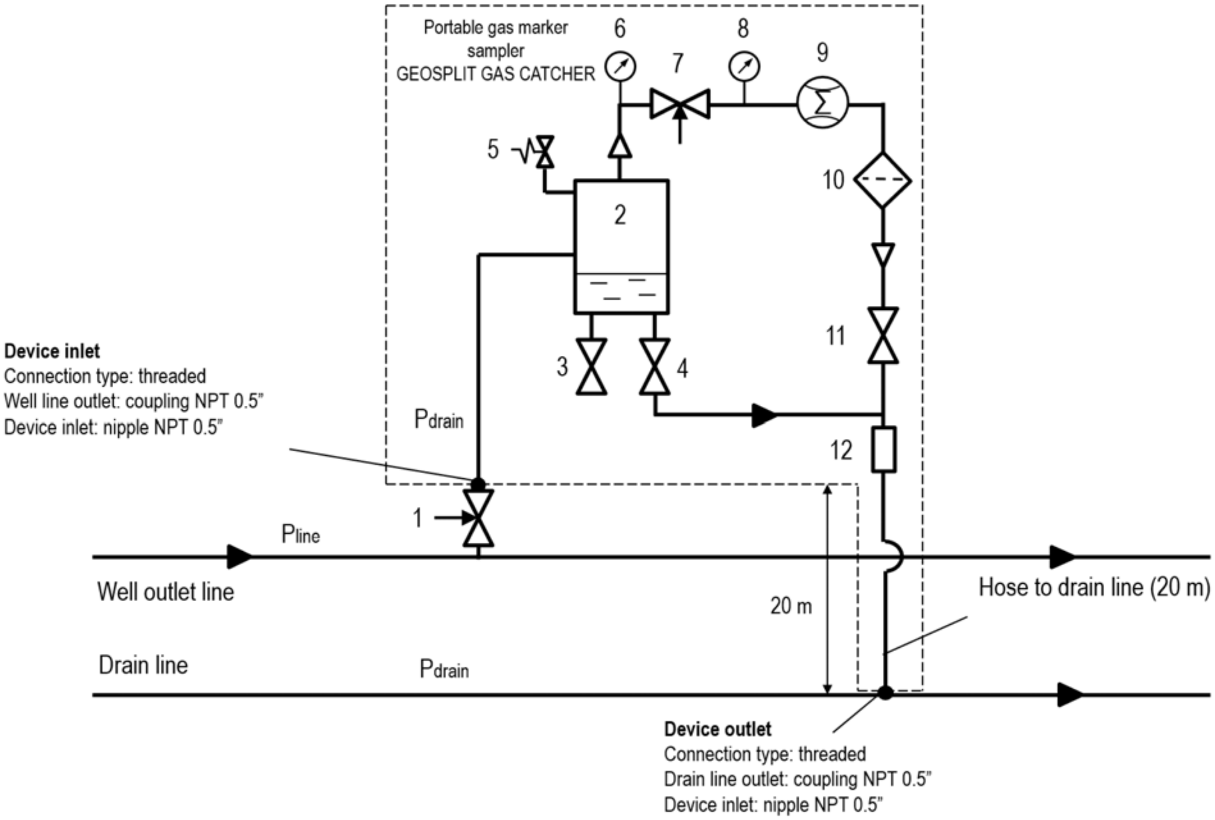

Figure 7—The process flow chart of the portable gas marker sampler:1 - control valve; 2 - separator; 3, 11 - process valves; 4 - drain cock; 5 - pressure relief valve; 6, 8 - pressure gauges; 7 - gas valve; 9 - gas flow meter-counter; 10 - filtering device; 12 - check valve

Figure 8—Gas marker sampler external view

The Device is connected to the existing surface piping of the well under survey. The input of the device is connected to a sampler, which is installed on the output line of the well under survey. The output of the device is connected to the drain (flare) line with a flexible sleeve. A needle valve 1 is located at the inlet of the device. It is used to adjust the flow of formation fluid and control the pressure in the separator by pressure gauge 6. The control needle valve 1 is crack opened during survey and the gas-fluid formation mixture is fed to the device inlet from the outlet line of the well. The separation of the gas and fluid phases is carried out in the separator 2, after which the gas phase enters the filtration device 10, where a membrane that traps gas markers is installed. Also, the gas flow rate is recorded in the gas line using a flow meter-counter 9, after which the gas flow is sent to the drainage line. When the separator is periodically filled with the fluid, it also drains into the drain line through the drain valve 4. The device is equipped with a check valve 12 to prevent overflows from the drain line, as well as a pressure relief valve 5 in case of emergency overpressure in the system.

At the end of the sampling, the inlet valve is closed, the fluid accumulated in the separator is discharged into the drainage line, the filter element is removed and transported to the laboratory for gas marker identification.

As can be seen from the above the process of gas marker sampling is carried out with no modifications and any interventions in the well-head equipment of the well under study.

Conclusion

This paper described the tried approach of marker monitoring system placement in completion assemblies and carrying out of 3-phase well monitoring by oil, water and gas. The solution assumes equipping each cassette or inflow control device with a set of marker indicators of the unique signatures that allows for obtaining inflow profile in numerical terms with unique identification of water or gas breakthrough source, and thereby improving information content of the test significantly.

it includes the example of identification of water inflow through the certain ICDs of the horizontal well and gas migration through the leaking packer.

New sampling technology tried in offshore project conditions and that completely excludes intervention into existing connections and pipeline infrastructure was described.

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