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Gas Breakthrough Identification in ERD Wells using Gas Tracers with Quantum Dots

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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.

Conventional PLT methods applied in extended reach drilled (ERD) wells have a number of limitations related to data relevance and well bore accessibility. The alternative method is deployment of tracer-based material while well completion process. This enables a stream of downhole data on demand without needs of well intervention using Coiled Tubing or Tractor services.

This paper describes an approach of deploying the dynamic tracer-based production logging monitoring systems as a part of well completion equipment. Special cassettes attached to slotted liners or ICV/ICDs carry out advanced polymeric composition for 3-phase monitoring for oil, water and gas, including off-shore project with extended reach wells (ERD).

Introduction

Studies of inflow profiles in horizontal production wells serves as the basis for making technical decisions that seek to increase efficiency in field development and optimize well construction solutions or capital workover operations. In this regard, the interest of production companies in well production logging technologies is conditioned by the potential significant cost savings and increase in the quality of production logging data.

Today, several conventional production logging methods are used:

1. Field and geophysical research with PLT;
2. Using ICD, ICV couplings (smart well completions ICD, ICV);
3. Using fiber optic sensors and additional software;
4. Tracer-based studies (marker technology).

Conventional PLT logging and marker-based studies can be distinguished among the methods listed above as they provide the most reliable production logging methods in terms of accuracy and reliability of the resulting data.

Undoubtedly, the adaptive smart completion system is an important tool for developing horizontal wells. This system can be adjusted independently considering the speed, phase composition and fluid pressure. In this case, production logging is carried out using fluorescent tracers placed in the filter. One part of the tracer dissolves when it comes into contact with water, and the others dissolves when it comes into contact with oil and, selectively, with gas. The signature of the tracers corresponds to the horizontal well interval, allowing for evaluation of the operation of a particular area. However, the inflow profile data obtained by analysis of the samples with tracers are most often ambiguously interpreted. In this case, fluorescent tracers are not monodisperse, i.e. their size varies greatly, introducing significant error into the model used for production logging and data interpretation. This method is more suitable for qualitative production logging, but not quantitative logging.

The production logging method that utilizes fiber optic sensors and specialized software also has its drawbacks. On the one hand, downhole temperature logging has visible advantages over traditional flow measurement methods for the quantification of low flow rates due to higher sensitivity. Despite this, the present method has limited measurement accuracy, and the simultaneous influence of several processes on the thermal field causes additional ambiguity during data interpretation. In addition, quantitative evaluation using temperature logging methods cannot be performed without obtaining reliable data. Since the informative capacity issues of production logging method using fiber-optic sensors, as well as processing and analysis of the obtained data remain open, the application of such sensors for well development cannot always be considered rational.

Tracer based dynamic PLT

The production logging method is based on the injection of marker-reporters that contain quantum dots in the proppant polymer coating. Quantum dots sized to several nanometers are chemically placed inside the insoluble microspheres. Those microspheres are about one micron in size. Billions of those polymeric spheres doped with quantum dots then placed inside of tapes made of 3D polymeric composite (Figure 1). Next, the markers are washed out and injected into the formation fluid. Samples are then taken from the wellhead and tested in the laboratory for analysis.

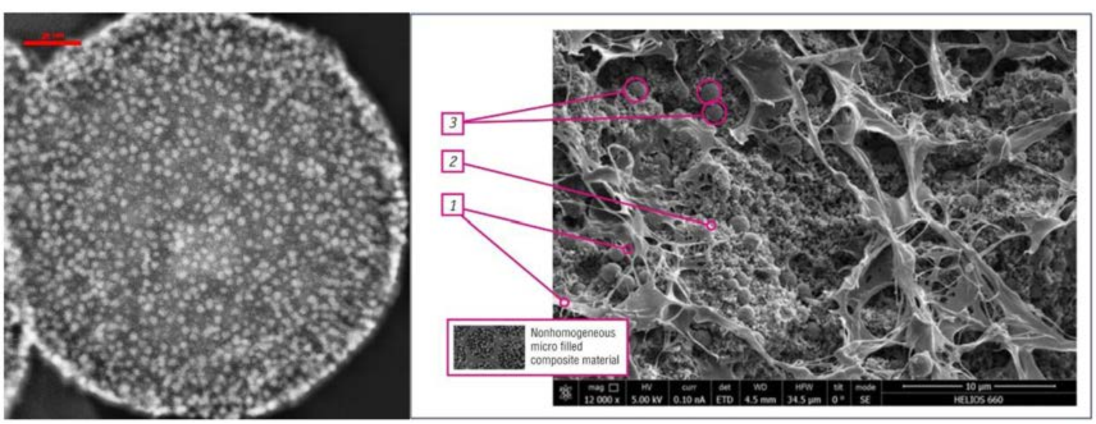

Figure 1—Polymeric sphere doped with quantum dots (on the left). Nonhomogeneous micro filled composite material with quantum marker-reporters in the scanning electronic microscope (on the right side): 1 – Frame; 2 – Filler; 3 – Quantum marker-reporters

This composite polymer matrix enables issuance of quantum marker-reporters into the formation fluid and gas with a steady concentration and duration facilitating long-term monitoring.

The analytical method for determining marker-reporters is based on the instrumental method – flow cytofluorometry or simply cytometry. The principle of operation is as follows: inhomogeneities in the sample line up exactly one after another with the help of a crimping fluid and a finely tuned hydrodynamic system. Next, they are irradiated using several lasers. After irradiation, the signals are recorded by various detectors. For each point, 15 different parameters are fixed, the most informative of which are fluorescence channels at different wavelength ranges. Marker-reporters are microspheres with quantum dots inside. These dots fluoresce in different colors, depending on the signature number or the marker code. Each interval of a horizontal well has cassettes with a dedicated tracer material (for oil, formation water and gas), allowing users to evaluate the contribution of each interval to the total production rate. Any time customer wants to do production logging survey the sampling procedure is carried out. Liquid sample are taken from sample point on wellhead. Gas sampling require installation of special device on the bypass line. Each sample is then analyzed using the sophisticated analytical hardware-software complex that employs flow cytometry principle. Based on the sample analysis results and their interpretation, the relative content of marker-reporters with various signatures was determined, allowing for switching to the percentage expression of inflows for each well interval with phase selectivity (Figure 2).

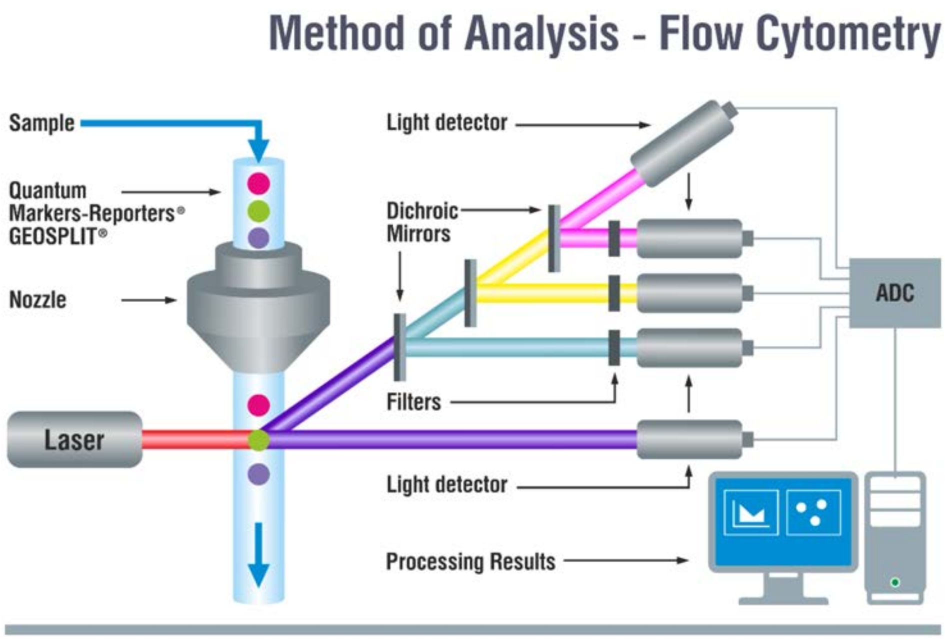

Figure 2—Process of markers identification.

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 plus 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 3 & 4).

Figure 3—Cassette carrying 3D polymer with markers.

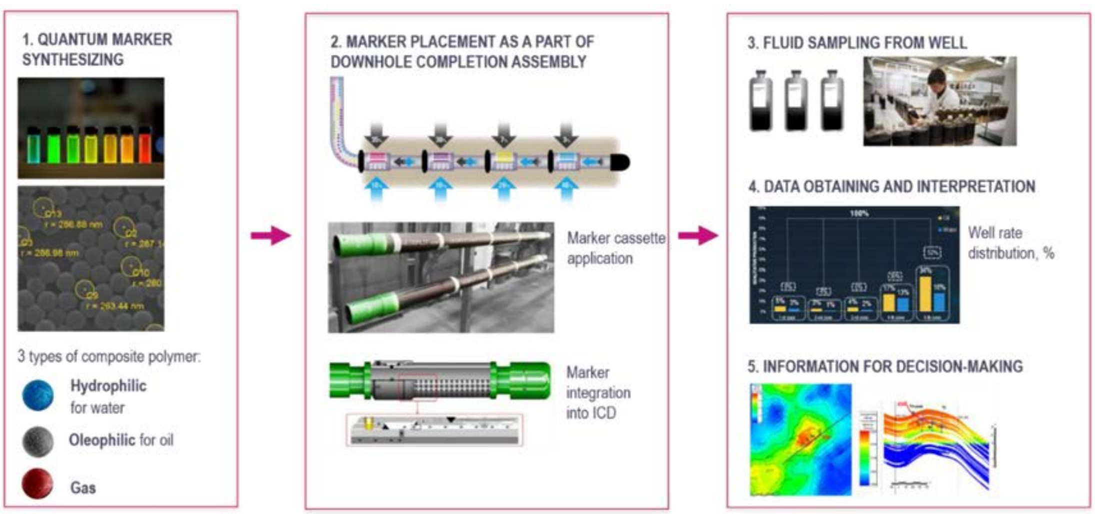

Figure 4—Well marker diagnostics and monitoring technology.

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.

The field overview

The Filanovsky oilfield in the north sector of Caspian field is being developed by drilling ERD horizontal wells from a single platform. By spring of 2020 7 wells have been successfully completed. Production wells will include extended-reach development (ERD) wells with horizontal sections up to 5,000 m. The Filanovsky field reservoirs are quite heterogeneous, and the bubble point pressure is very close to reservoir pressure. These factors result in a high risk of water/gas breakthrough from high-permeability zones and the possibility of gas-water coning. The reservoir's drive mechanism is a combination of gas cap and water drive.

One of the major challenges with well placement and field development is the presence of the massive active gas cap above and the underlying waterbearing reservoir where the oil-bearing zone is only 20 meters thick. In highly permeable formations with good vertical permeability, gas and water coning can decrease oil production from the very first days of the well. The well placement strategy was to drill a long horizontal section at a maximum distance (~15 m) from the gas cap. This was done to avoid gas breakthrough and maintain a low drawdown pressure to produce the oil. Apart of well trajectory placement a drawdown management is vital to achieve target oil recovery. The fact that most wells are produced with a constant oil flow rate with constant gas-oil ratio (GOR) before gas or/and water breakthrough is conventional. However, gas coning in Production wells may drastically reduce the oil production. From operational and economic point of view, this occurrence is not good as the gas handling capacity is a problem.

QA/QC for cassette testing

Torque and drag (T&D) modeling is regarded as extremely helpful in well planning because it helps to predict and prevent problems that might occur during the process well completion equipment deployment. Although T&D software has existed since the 1990s, some confusion still exists over the validity of the models that are used to characterize drilling operations, especially as we extend the length of modern horizontal wells. Moreover, it seems that only minimal improvements have been made to the underlying mathematical models over the last two decades. Planning deployment of cassettes with polymeric material in extended-reach wells, T&D testing using special equipment is the best way quality assurance. Before initiating any project any design of cassette is the subject to acceptance for external mechanical impact resistance:

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

The Figures 5 & 6 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 5—Marker cassette prototype model installation on a base pipe.

Figure 6—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 7).

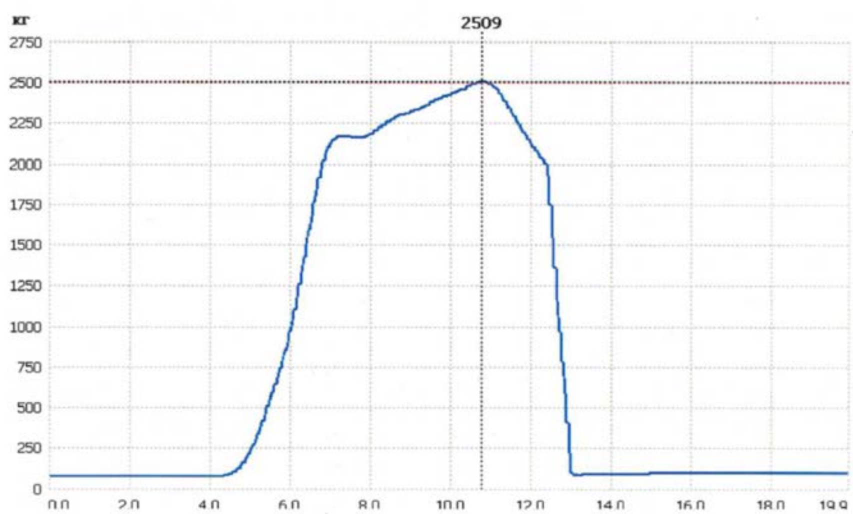

Figure 7—External torque records during the tests

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.

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 integrity (Figure 8). In case of packer leaks the markers of dedicated signature will be found in the well fluid samples.

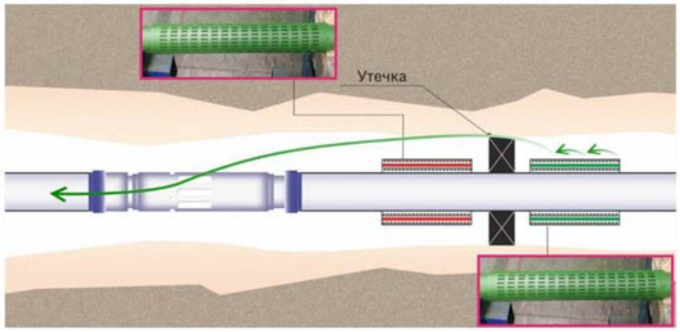

Figure 8—Straddle parker sealing monitoring system in the horizontal well

The Figure 9 shows an example of 3-interval horizontal well marker diagnostics using ICD equipped by unique signatures of markers and packer sealing monitoring system:

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

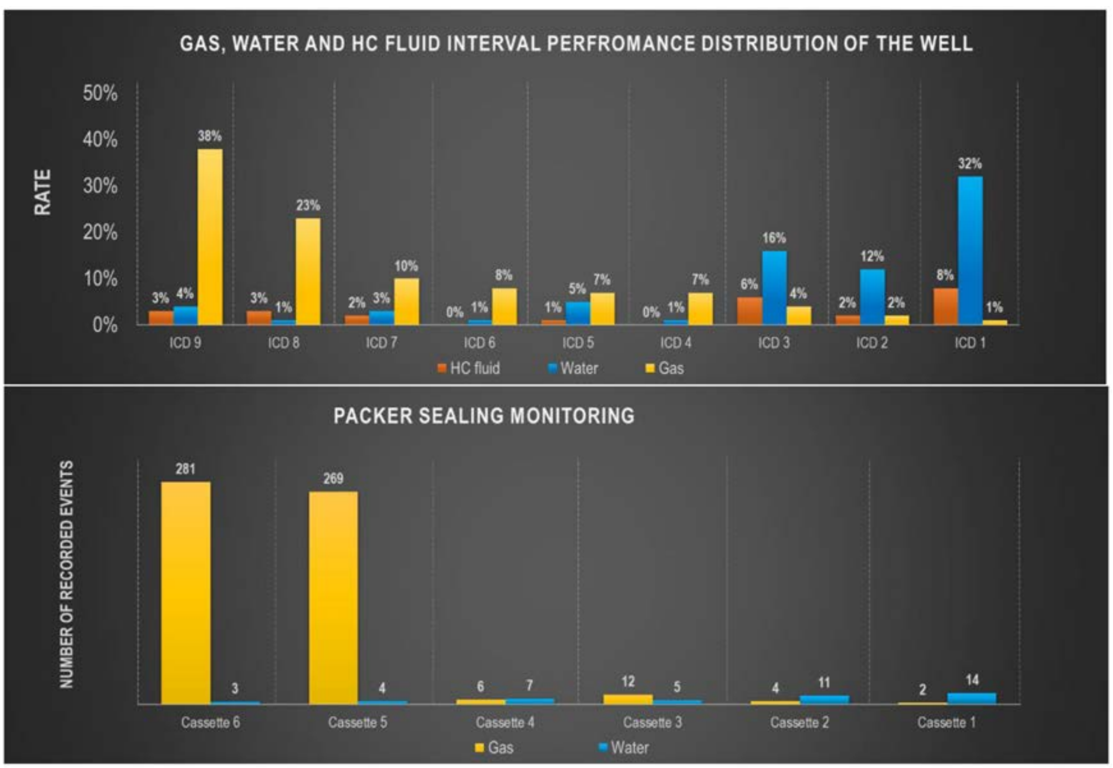

Figure 9—The results of horizontal well marker diagnostics with 3 intervals with numerical identification:- inflow profiling for each ICD (oil, water and gas) - packer integrity (gas, water).
Note: ICD 1 is the «heel» zone and ICD 9 is the «toe» zone of the well.

The sampling of oil and gas has been carried a single time in March 2019. Access to the offshore was blocked due to COVID travel ban. 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 10 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 11.

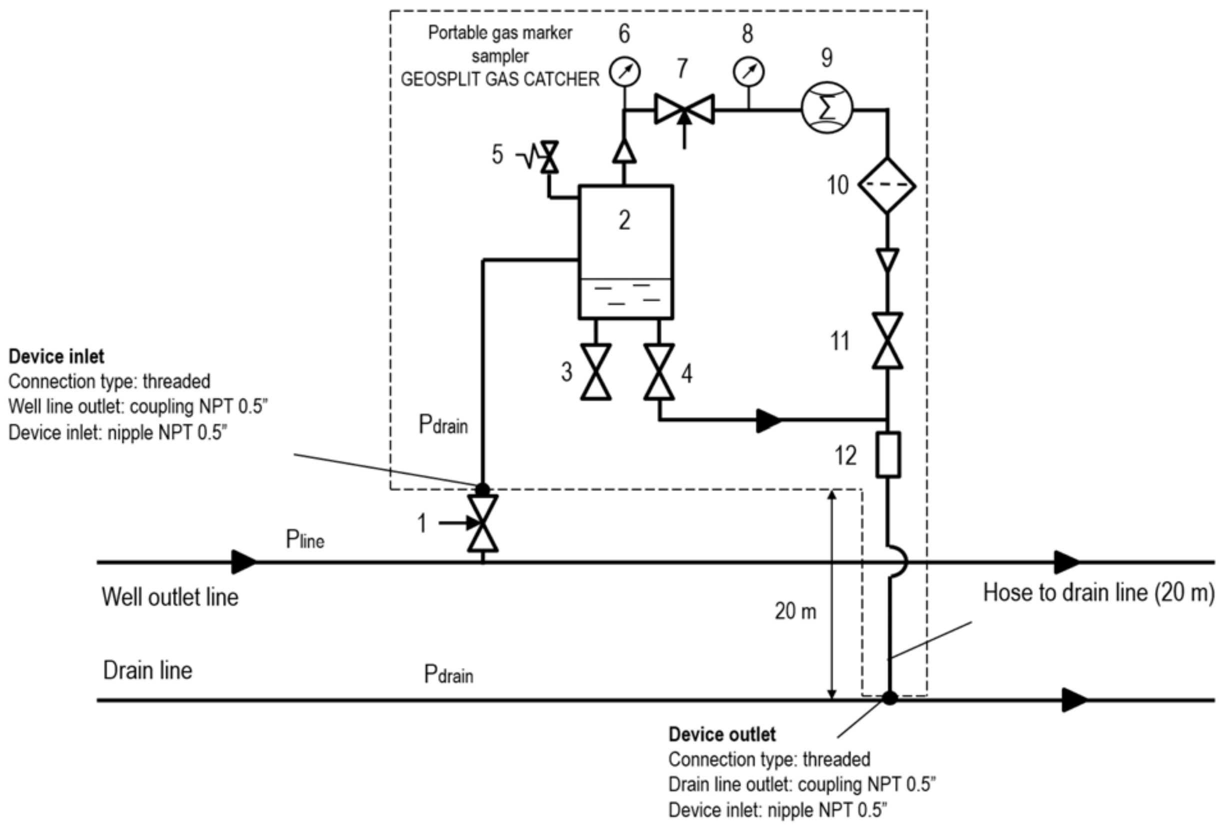

Figure 10—The process flow chart of the portable gas marker sampler: 1 - control valve; 2 - separator; 3, 11 - process valves; 4 - drain cock; 5 - pressure relief valve; 6, 8 - pressure gauges; 7 - gas valve; 9 - gas flow meter-counter; 10 - filtering device; 12 - check valve

Figure 11—Gas marker sampler external view

The device is connected to the existing surface wellhead piping. 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

The early gas breakthrough which happened right after well was put on production became a surprise for petroleum engineers. Reasons for that are still under investigation. However, the technology of dynamic production logging has confirmed the capability of 3 phase monitoring and early gas breakthrough identification. The next step in the project development will be an effort to close ICDs on the "toe" zone of horizontal lateral and ensure improvement in the inflow profile. In the next five years, we plan to execute dynamic tracer-based production logging twice a year. The aim of deploying this technology in ERD wells is a full avoidance of well intervention which requires the implementation of inflow control devices with remote control.