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Application of Quantum Dot Markers for Production Logging in Horizontal Wells

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SUMMARY

This paper provides an overview of one of the alternative methods of production logging in horizontal wells which doesn't require well intervention using PLT tools, Coiled Tubing or Tractor services. This method employs marker technology of quantum dot markers placed in the reservoir during stimulation. The method also allows reducing the cost as well as the complexity of acquiring downhole data. Unlike the conventional PLT, the technology described below can provide production logs on demand during one year after well stimulation.

Abstract

World experience shows that horizontal wells, relatively vertical or directional, that develop the same reservoir, have production rates on average 3-8 times higher, which allows reducing operating costs and optimizing the grid of producing wells. Though the number of horizontal wells is rapidly increasing, the production of hydrocarbons is not always up to the designed volume. In this regard, acquiring the knowledge on the performance of producing intervals is an important task for operating companies to fully optimize the productivity and maximize the recovery as well. Moreover, the quality of well completion and reservoir management decisions for production wells largely depends on the production logging data such as mechanical flowmeter and fluid capacitance surveys.

Until recently, there is no alternative to wireline downhole tools being used to evaluate the placement of fracturing proppant or acids, production rate and zonal water breakthrough. In practice, well intervention in horizontal wells requires implication of coiled tubing or tractor services to deploy logging tools downhole. The success of well intervention depends on several factors and among of these are as follows: well accessibility, completion IDs and length of the horizontal lateral, etc. There are also key aspects to be considered such as the significant cost of well intervention and the availability of wireline and coiled tubing equipment.

One of the alternative methods of production logging in horizontal wells is quantum dots marker technology. The method also allows reducing the cost as well as the complexity of acquiring downhole data. Unlike the conventional PLT, the technology described below can provide production logs on demand during one year after well stimulation.

The technology of production logging without well intervention using quantum dot marker-reporters

Production logging data can be obtained in an alternative way using tracers embedded in proppant which are pumped downhole during fracturing. The main advantage of quantum dots tracer® technology is its ability to monitor the formation fluid production per zone at any time during a year after fracturing. Implementation of the technology is time efficient and does not require field equipment as well as crew for operation, which reflects on operating costs carried by customers. Indeed, the placement of tracers into the oil reservoir for a long-term period and the subsequent analysis of marker-reporters carried throughout the well and into the surface brings well management on a qualitatively new level.

The specifications of horizontal laterals demand further sophistication of downhole tools such as increasing the number of spinners to cover wellbore cross section area. Further, when coiled tubing deploys logging tools in a wellbore, it may cause a choking effect resulting to the distortion of the downhole production rates data. Often, in horizontal wells, the standard mechanical flow measurement frequently becomes uninformative and instead, characterise fluid that filled up the lateral rather than the actual performance of the production intervals [1]. In comparison with vertical wells, the possibilities of de-noising inflows in horizontal wells by methods of thermometry are limited. This is due to a slight variation in geothermal temperature along the length of the horizontal section and lower differential pressure drawdown per layer than in vertical wells.

An equipment for measuring spectral noise downhole could help to detect a wave pattern of acoustic emission and to identify medium- and high-frequency anomalies associated with filtration of fluid through the rock within the critical matrix. These anomalies allow the determination of producing intervals differentiated from the low-frequency noise associated with the flow of formation fluid in the wellbore. However, this method requires non-stationary measurement technologies requiring periodic and time-varying measurements. The reason behind it is a sudden change in the wellbore fluid composition after the well is being put in production. The use of standard PLT downhole tools equipped with single flowmetry spinner is not adequate for horizontal well and leads to interpretation errors [5].

Unlike in production logging with quantum dot markers, conventional downhole tools are designed to provide production data during well intervention only and do not give a dynamic picture extended in time. Finally, well intervention has some risk of coiled tubing stuck or loss of downhole tools in a well with a subsequent costly fishing operation.

Thus, there is a high demand for the development and application of more accessible production logging technologies to be used in horizontal wells. This can be addressed using alternative methods of production logging such as quantum dot tracer technology.

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The technology features a synthesis of the combination of marker-reporters made of a few quantum dots and a mixture of the polymer-based chemical composition [4].
Colloidal quantum dots irradiated with a laser fluoresce in different areas of the electromagnetic spectrum due to quantum confinement [2, 3].

Quantum dots are more chemically stable than natural fluorophors because of their chemical composition, which reduces the photobleaching effect compared to organic dyes and can withstand the impact of acids and high temperatures. The emittance of a particular spectre of light can be detected using GEOSPLIT analytical hardware-software complex. Several quantum dots joined together creates a unique and traceable marker-reporters element. There could be a large number of possible tracer signatures (more than 60) that exclude the chance of misinterpretation during the lab analysis. This distinctive feature of quantum dot marker-reporters technology is essential in multistage fracturing of more than 30 production intervals in a single horizontal well.

The polymer coating of fracturing proppant contains millions of marker-reporters and is designed to degrade gradually when in contact with hydrocarbons and water. During the fracturing operation, some proppant with tracers follow the mass of a conventional proppant. After the introduction of proppant into the formation, the coating gradually releases markers to formation fluid and further carried out into the surface. The marker-reporters can be captured either in oil or water phase of formation fluid. Due to the nanosize of markers, these materials do not have enough energy to make a transition from one phase to the other. Hence, each phase of formation fluid has its own indicators. The process continues and is without interruption for at least a year. On demand, samples of formation fluid are taken from sample point located in the production line and studied in the laboratory.

As a result, events are recorded that are optical inhomogeneities in an optically homogeneous mobile phase. Since the optical markers used have a characteristic "glow" each in its spectral region, the software used by us allows us to separate each of the signatures used for analysis among a large number of "events" (Figure 1).

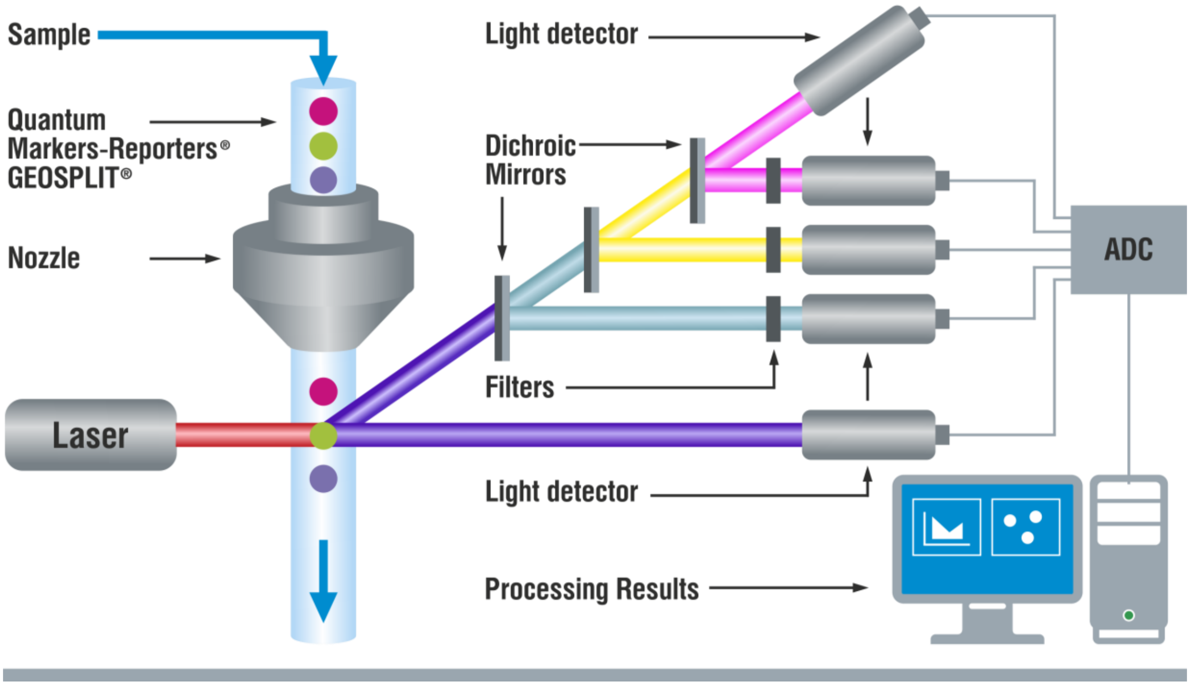

Figure 1. *Flow chart of the analytical hardware-software complex «GEOSPLIT».*

The software used for optical identification of each code makes it possible to separate out their characteristic area of the spectral space (3D image) and to count the registered "events" in each such area. The definition of the characteristic regions described above is based on the data of laboratory experiments modeling each signature separately, as well as their numerous combinations. The obtained data is interpreted by software and visualized in the form of inflow charts along the stages of the fracturing in time and accumulated production rates for liquid hydrocarbons and water in each of the stages.

The technology validation

The laboratory testing used an especially designed laboratory bench with a horizontally located barrel equipped with injection ports and performed at seven (7) intervals. Each interval was loaded with proppant having individual signatures of quantum dot tracers. Small electric pumps were used to inject a mixture of oil and water though the proppant simulating water breakthrough in the horizontal lateral. Injection rates and oil-water ratio were gradually altered throughout the experiment. The study was conducted based on 12 samples taken in 7 days. According to diagnostic results, and in accordance with the changes in injection rates, sequential oil inflow drops were detected in intervals 7 and 6. At the same time, both intervals showed a smooth increase in water inflow as detected by flow cytometry. The study illustrates that the total rate of water output as presented in Figure 2 revealed the increase of water production in intervals 7 and 6.

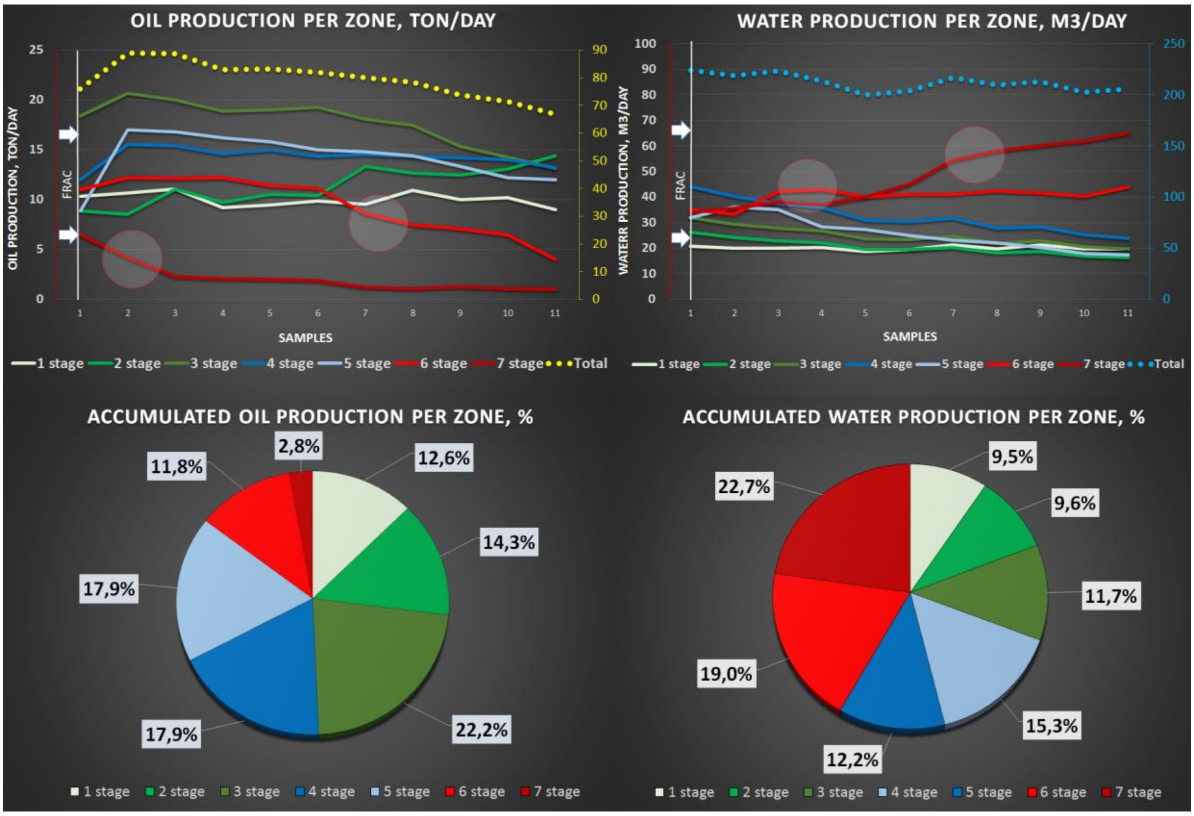

Figure 2*. Consecutive decreases in oil inflow at intervals 7 and 6.*

Conclusion

Qualitative and quantitative analysis of quantum dot marker-reporters in samples of formation fluid allows making informed conclusions about the performance of productive intervals of horizontal well. Application of the technology showed the following benefits:

- The possibility of monitoring inflows for a long period of time, in contrast to a one-time logging operation;
- A significantly lower resource intensity and cost;
- Confidence in conditions when the traditional downhole logging operations are complicated.

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