Well-test during synchronous-separate operation

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Abstract. This work aims at searching for the best research technology for synchronous-separate development of multilayer oil and gas deposits. For conditions of the Western Siberia, single pump designs of layouts for synchronous-separate operation with isolation packers and various locking devices for beds isolation (electromagnetic, electromechanical and hydraulic control valves) are most preferred in most cases. These devices make it possible to effectively monitor and regulate oil production process for individual objects of development. Located under each valve are pressure and temperature sensors for monitoring the process of valves closing and opening and thermo-hydrodynamic well-test. In course of the study filtration characteristics of the exploited layers were determined.

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Introduction

Recently in oilfield practice, transition to reusable production target and layers commingling has been often used. Systems of synchronous-separate development (SSD) and synchronous-separate injection (SSI) are deployed. These technologies are applicable to development of new multilayer deposits as well. With that, close attention should be paid to monitoring development of reserves in a multilayer object.

Analysis of the existing arrangements for synchronous-separate operation of several layers showed that in conditions of Western Siberia, single pump designs of layouts for synchronous-separate operation with isolation packers and various locking devices for beds isolation (monitoring system with layers isolation) are most preferred in most cases [1]. To optimize wells operation during SSD using similar arrangements, a number of devices has been created that make it possible to effectively monitor and regulate oil development for individual development targets. These include electromagnetic, electromechanical, and hydraulic valves. Electrically controlled valves are controlled by a control station, and hydraulic valves are actuated by differential pressure in the annulus and below the packer using water or oil injection [2]. These designs are protected by patents.

Configuration has been tested with isolating packer and an electromechanical valve, which is controlled by a control station and isolates the lower production horizon. As a result it was found that the system makes it possible to measure parameters in the upper horizon separately with predefined draw-down pressure on the horizon. At the time of measuring, build-up curve for the lower horizon is recorded in real time with a device installed under the valve. Pressure gage data are sent to the control station. Using the build-up one can define hydrodynamic parameters of the horizon and their change over time [3, 4].

In order to comply with all requirements for monitoring reserve recovery [5] using single pump configurations, an electromechanical valve has been designed that makes it possible to implement the fluid flow regulation function. Control valve makes it possible to create differentiated draw down on the horizon.

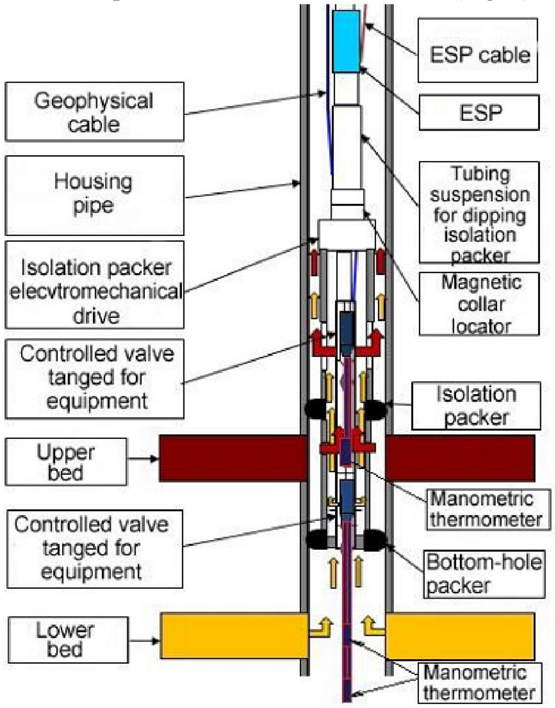
Advantages of layouts that use one electric submersible pump (ESP) are:

- greater submersion depth;
- wide range of total feed;
- operating time close to that of conventional wells with ESP;
- simplified wells repair and overhaul;
- low cost of equipment;

Disadvantages:

- shared draw-down in horizons;
- mutual influence of horizons is not yet studied enough.

To eliminate these disadvantages, an SSD arrangement has been implemented with one ESP and possibility to isolate any horizon. Valves are operated from a control station; valves are at the same time regulators of flow from horizons. At the control station, percentage valve closure can be set, i.e., one can create optimal draw-down for horizons (Fig. 1).



Bed layer

Figure 1 - SSD layout with one ESP and the possibility to isolate any horizon for well-test.

Under each valve shanks with pressure-and temperature gages are located for registration of pressure and temperature, which are indicators of valves opening and closing. During valve closing, build-up is registered with high enough quality, since the influence of the borehole that complicates data interpretation is excluded [6].

Use of this design makes it possible to operate wells with three or more horizons.

Wells with the above configuration are fully automated, since under certain control station settings it is possible to ensure valves closure with required regularly and automated fixation of parameters of separate horizons' operation. This scheme is almost universal and is applicable to any well with SSD.

Well-test with this arrangement can be performed without lifting down-hole equipment. This makes it possible to significantly reduce time and financial expenses.

Thermo-hydrodynamic well-test is aimed at determining working intervals of a multi-horizon target, intensity of production intervals operation, filtration characteristics of horizons, horizon pressure and temperature, as well as the state of the bottom-hole formation zone. Research results lead to the conclusion about the need for geological and technological measures and make it possible to assess the level of horizons interaction during synchronous operation [7].

Thermo-hydrodynamic well-test is performed in the steady and the unsteady filtration modes.

Well-test in steady-state condition is based on creating several cycles of predefined draw-downs (at least two) with liquid rates measurement. Number of cycles, their duration and the range created draw-downs is determined in accordance with tasks. Based on the results of the studies, an indicator diagram is built (indicator curve (IC)) in coordinates output *(Q)* - draw down on horizon *(ΔP)*. Processing and interpretation of well-test results in steady modes is made according to well-known and widely studied methods [3, 6, 8]. The aim of the study is determining the well productivity factor and the optimum draw-down.

Well-test in unstable modes of filtering using the method of build-up recording makes it possible to determine filtration parameters such as hydraulic conductivity, permeability, and the skin-factor, as well as to trace the dynamics of changes in productivity and the skin factor after each well shut-down [4, 9, 10, 11].

Devices that register pressure and temperature are opposite each tested interval in the multi-horizon target, which makes it possible to accurately assess effective bed thickness. The main diagnostic feature is temperature change after instantaneous well commissioning, specified by manifestation of barothermal and choke effect of Joule-Thomson. One device is located in well's sump (Figure 1) and is a reference one, since in this zone temperature change due to choke effect does not occur [7].

At the stage of processing results of the study, consolidated barogramms and thermogramms from all devices are built.

In barogramms specific points are shown for well mode change, differential pressure and temperature change are defined for these points and adiabatic coefficients are calculated in the areas of adiabatic compression and expansion manifestation [12].

Based on a qualitative assessment of choke effect manifestation at steady filtration (visual comparison of devices thermogramms using a tester located in the sump, where the influx is certainly absent), a conclusion is made about effective beds (horizons) thickness.

This diagnostic manifestation of effective beds in studied horizons has been found basing on mathematical modeling of thermo-hydrodynamic processes in the "well- horizon" system. The method is based on the energy conservation equation by E.B. Chekalyuk [13]. The main diagnostic manifestation is temperature change after well commissioning, specified by manifestation of barothermal (in case of unstable filtering of horizon fluid) and choke effect of Joule-Thomson (in case of stationary filtering). In initial moments after "instantaneous" well commissioning, adiabatic effect of expansion (contraction) occurs in the wellbore, and then barothermal effect of heating expansible fluid. In these moments, the effects of calorimetric mixing of streams from various intervals, and heat exchange processes with surrounding rock can be neglected. The degree of manifestation barothermal effect is determined by the rate of fluid filtration, i.e. by the rate of temperature change opposite to effective intervals of a multi-horizon target, the rate of fluid filtration is defined in these intervals and therefore, flow rates of individual horizons. Consolidated thermogramms recorded by equipment installed in the intervals of the horizon make it possible to determine intensity of the flow from each horizon separately and the quantitative share in the overall well effectiveness [12]. Results of thermodynamic studies will show whether the flows from various horizons influence each other. Reliably determined are the intervals of horizons and their effective thickness.

Processing and interpretation of research results in unsteady modes (using build-up method) is made taking into account working thickness of the horizons studied [14, 15]. Measured and calculated parameters for the IC and build-up ensure confident determination of filtration system parameters, allowing further influx modeling, optimization of oil recovery, planning and evaluation of the effectiveness of geotechnological activities.

Important is the fact that any well stop (even unplanned one made for technical reasons) is interpreted as thermo-hydrodynamic well-test. This makes it possible to dynamically track changes in filtration properties of each horizon, such as skin factor, permeability, etc.

Conclusions

The technological solutions for operation of multi-horizon targets proposed in this work are universal and suitable for operation of three or more horizons. Devices described, such as control valve, make it possible to create different draw-down during operation of several horizons with an electric submersible pump (ESP). The proposed technology of horizons study will make it possible to monitor operation of down-hole equipment and to obtain most complete information about productive horizons without tripping operations.

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