The control of unprocessed oil stratum debit restoring by method of ultrasound influence with well neutron generator

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Abstract. The examples of experimental studies of oil stratum debit restoring by method of ultrasound influence to stratum are given. The method of control of such unprocessed oil stratum restoring is proposed. It uses well neutron generator with vacuum accelerating tube and neutron reagent method with pumping of neutron absorbing salt solution to stratum. The results of its successful testing are presented.

1. Catalytic action of microwave radiation

During the operation of an oil well, its production rate is reduced as a result of contamination of the fluid recovery zone. To restore it, the ultrasonic influence (UI) to stratum is applied.

Figure 1 shows a general view of the hardware complex UI in the process of operation.

Figure 1. General view of the ultrasonic influence complex:
1 – stratum with productive fluid, 2 – well source of acoustic oscillations, 3 – cased well, 4 – geophysical load bearing cable, 5 – ground geophysical station with generator, control panel and winch.
Table 1 selectively presents the data on the increase in the production rate $\Delta$ and additionally produced oil $Q$ for 8 wells, illustrating the efficiency of the UI in the example of the Fedorovsky oil field.

Table 1. The increase in the production rate $\Delta$ and additionally produced oil $Q$.

| Well No. | $\Delta$, t / day | $Q$, t |
|---------|-------------------|--------|
| 1063    | 6.0               | 500    |
| 1876    | 5.6               | 846    |
| 1886    | 8.0               | 720    |
| 1914    | 0                 | 0      |
| 1967    | 8.7               | 783    |
| 2612    | 13.0              | 720    |
| 2634    | 0                 | 0      |
| 2850    | 40.6              | 14846  |

UI method was used to process 74 wells with a success rate of about 76%. The increase in production rate per one well was 9.9 tons per day.

As can be seen from the table, there are objects (wells No. 1914, 2634) for which the application of the UI technology does not give a positive result. In work [1] a method was proposed for identification of such wells to exclude them from the sphere of preventive actions of production rate recovery. To implement it, it is necessary to use a controlled well emitter of fast neutrons [2] generated in the pulse-periodic mode when the accelerated deuteron flux interacts with a metal target saturated with tritium, where the nuclear reaction of synthesis $T(d, n)^4$He is carried out. The target is located on the cathode electrode of a sealed vacuum accelerator tube. One of the versions of its design developed in VNIIA [3] is shown in figure 2.

Figure 2. Schematic section of the accelerator tube:
1 target; 2-diode accelerating system; 3-source of deuterons; 4-insulators.

The change in permeability of the collector was analyzed by neutron logging methods [4]. The general scheme of the hardware complex implementing any of the method modifications is shown in figure 3.

When replacing quasi-cement formations in the pores of the oil collector, the environment under investigation begins to effectively slow down the fast neutrons generated by the emitter. Their radiative capture increases at the same time. As a result the fluxes of $\gamma$-quanta to the detector and the counting rate of their registration are increased. On its growth it is possible to judge success of UI carrying out. The dependence of the integral count of the $\gamma$-quantum detector $A(x)$ on the coordinate delayed along the wellbore in the region from the beginning of the oil stratum with a thickness of about 8 m taken before and after the realization of UI is shown in figure 4.

The lower curve corresponds to the measurement of the integral count of $\gamma$-quantum before UI, the upper curve after it. The relative error in the measurement did not exceed 15%. A comparison of the curves obtained indicates an increase in the integral count of the $\gamma$-quantum recording events during UI, and, consequently, an increase in the oil saturation, as well as the permeability of the well bottom zone.
Figure 3. Schematic diagram of the hardware complex:
1 – well device with a protective bar-resistant housing, 2 – neutron source based on accelerating tube, 3 – detection system, 4 well executive and telemetry systems, 5 – load carrying cable, 6 – complex of ground equipment (logging station), 7 – ground control and telemetry systems, 8 – onboard computer, 9 - depth indicator of well device.

Figure 4. The typical experimental dependences of the integral count of the $\gamma$-quantum detector (relative units) on the coordinate delayed along the wellbore taken before UI (curve 1) and after UI (curve 2).

Registration of thermal neutrons diffusing to the helium detector located in the well device was carried out in another experiment. The obtained dependences of the integral count of thermal neutrons are similar to the corresponding dependences of the integral count of $\gamma$-quantum shown in figure 4. The results of this experiment also indicate the effectiveness of the UI.

A method for determining the state of a productive formation [1] by a pulsed neutron method with injecting a neutron absorbing substance into the reservoir (NaCl, CdCl$_2$, GdCl$_3$, etc.) was implemented in the third experiment. During the experiment, the time spectrum of thermal neutrons produced in the process of slowing down fast neutrons generated by the emitter in a pulsed mode was analyzed. The spectrum is characterized by the following time dependence of the thermal neutron flux detected by the detector:

$$n(t) \approx n(t_0) \exp[-\lambda(t-t_0)]$$

where $t_0$ is the registration start time, $\lambda$ is the decrement of the neutron flux decay proportional to the macroscopic cross section of their radiative capture. 6 measurements were taken at one well. At the 1st (background) measurement, the initial decrement $\lambda$ was determined. Then a NaCl solution was pumped into the formation, and the 2nd measurement was carried out. Further, the formation was
exposed to ultrasonic radiation at a frequency of 20 kHz, and another 4 measurements were carried out every two hours. The results of measurements of $\lambda_1$, $\lambda_2$ for two points of the productive formation, separated by a distance 2 m along the wellbore, are presented in table 2.

Table 2. The results of measurements of $\lambda_1$, $\lambda_2$ for two points of the productive formation.

| Measurement No. | 1   | 2   | 3   | 4   | 5   | 6   |
|-----------------|-----|-----|-----|-----|-----|-----|
| $\lambda_1$, ms$^{-1}$ | 4.0 | 5.5 | 5.3 | 5.2 | 4.5 | 4.1 |
| $\lambda_2$, ms$^{-1}$ | 3.0 | 5.0 | 4.6 | 4.5 | 4.1 | 3.1 |

Table data indicate that after UI the decrement is restored to the initial value within 8 hours. This indicates a rapid releasing of the reagent from the formation, which means its good hydrodynamic connection with the well, which determines the effectiveness of the UI method. A solution of GdCl$_3$ can be used to increase the contrast of measurements.

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