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THERMAL CYCLE OPTIMIZATION WHEN PROCESSING THE BOTTOM-HOLE ZONE OF WELLS

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ABSTRACT

Most of the liquid oil of all types estimated today represents the category of heavy-oils. This leads to decrease in oil production and more extraction of water. Enhanced oil recovery is a method using sophisticated techniques that can deal with such sort of oils and alter the original properties of oil. Thermal Enhanced Oil Recovery (EOR) remains the most frequently used method for extraction of heavy oils. In this work, irreversible changes in rocks that lead to an increase in formation permeability have been studied and, as a result, to an increase in the production flow rate of production wells and for injection wells, an increase in their injectivity. New methods and technologies have been developed for the intensification of thermocyclic well treatments.

A computer program based on mathematical model was developed, which allows predicting changes occurring in the well and near the well space. In this model, the main characteristics of the process of cyclic thermal impact on the bottom-hole zone can be used to predict field temperatures in the well and in the formation, as well as changes in the permeability of rocks. To improve the efficiency use of the model and increase the heating zone, a new method of thermal cycling impact on the bottom-hole zone of the well was developed.

Keywords: Thermocyclic impact, Permeability, Porosity, Well treatment, EOR.

I. INTRODUCTION

Thermal methods have been used in Russia, USA, Venezuela and other countries of the world since the beginning of the industrial development of oil fields. For some fields, thermal heating reduces the viscosity of oil, while for others, it is effective to remove asphalt-resinous and paraffin deposits [1,2].

Laboratory and field experiments have shown the prospects of effective use and modification of technologies for thermal cycling methods of well bottomhole treatment [3,4].

The theory and practice of thermal and thermocyclic effects on oil reservoirs are devoted to the work of many researchers [5,6,7].

The thermocyclic effect on reservoir rocks differs from other heat treatment schemes in that the heat flow in the well during heating does not remain constant, it changes according to a periodic law [8,9,10,11,12]. During this treatment, damped temperature fluctuations occur in the bottom-hole zone of the formation at a certain interval from the well wall, affecting the reservoir and causing alternating temperature stresses in it. Under the action of these stresses, additional microcracks appear in the structure of rocks.

The effectiveness of periodic heat treatment has already been determined in a number of studies [13,14,15]. However, the technological efficiency of periodic heat treatments was considered from the point of view of saving energy resources, as well as optimal use of the "Park" of heating units.

These works did not take into account the processes occurring in rocks, there is no description of changes in the pore space, the cement component. Although it should be noted, that under certain conditions these changes become irreversible.

II. METHODOLOGY

In this work, it is precisely the irreversible changes in rocks have been investigated .These changes lead to an increase in permeability and, as a consequence, to an increase in the flow rate of production wells and the injectivity of injection wells have been investigated. New methods and technologies have been developed for the intensification of thermocyclic treatments.

Laboratory studies conducted in previous works [16,17,18] showed changes in the permeability of reservoir rocks under thermocyclic influences. It should be noted that in most cases, the permeability of sandstones increased (the increase in oil permeability of sandstones was noted in all test samples from 0.6 to 10.7%, and in water permeability-from 3.1 to 19.4%). While in siltstones, the changes were less significant (oil permeability increases from 1.1 to 8.2%, water permeability-from 0.36 to 19.5). In limestone samples, changes in permeability were the least significant (oil permeability increased from 0.1 to 3.3%, water permeability increased from 0.6 to 15%, and some samples did not react).

To apply thermocyclic effects in field conditions, it is necessary to study the influence of a number of technical, technological, geological, lithological and other parameters on the flow rate of wells.

In work [19], a mathematical model of thermocyclic impact was constructed, which makes it possible to predict changes in the field reservoir temperature and well flow rate by reducing oil viscosity and improving rock permeability.

As well known, the viscosity of the flowing fluid and the permeability of the formation depend on temperature. Fig. 1 shows the temperature dependence of the viscosity of oil obtained from well No. 7080 of the Berezovsky field.

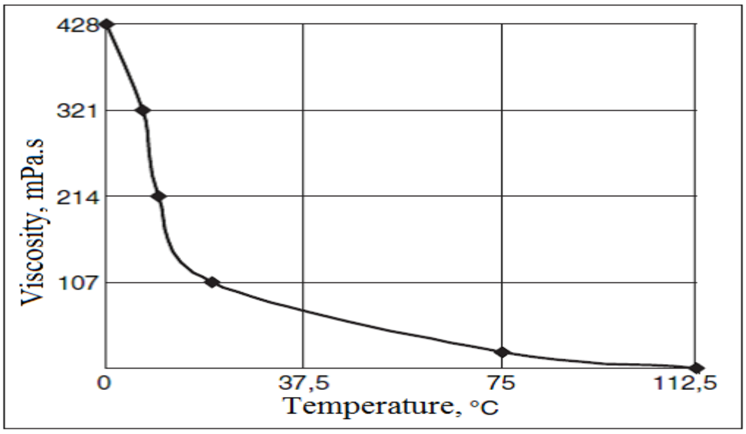

Figure 1: Change in oil viscosity with increasing temperature

Regarding the permeability, we assume that in a weakly permeable zone with an increase in temperature, the permeability increases and reaches the initial (before starting the well) at 50°C.

Further temperature change up to 200°C does not significantly change the permeability, but increases the temperature beyond 200°C leads again to a decrease in permeability due to coking of oil. Thus, when modelling thermocyclic influence, we select the range at which the influence is most effective.

To determine the reliability of the above conclusions, experimental field studies were conducted. Thermocyclic influence was applied to an oil reservoir with an effective thickness of 9 meters, lying at a depth of 1160 meters through well 7080 (block 3, Berezovskoye field). The flow rate of this well before the start of the thermosyclic impact was 1 m3 / day. Properties of the extracted products and the producing formation: density- 917 kg / m3, water cut - 40%.

The heater power during heating was 2 kW / m. The total duration of thermocyclic exposure was 3 months.

During this time, 5 heating and cooling cycles were performed. If we take for example first cycle, so its total duration was 21 days, including a heating cycle of 9 days and a cooling cycle of 13.

Based on a mathematical model, a computer program "Bitumen" was developed, which allows predicting changes occurring in the well and near the well space. For the calculations, the actual values for the well are entered into the program: borehole diameter, kinematic viscosity, thermal conductivity of rocks, well production, flow rate before heating, effective reservoir capacity, reservoir permeability, oil coking temperature and etc. The heater parameters are also taken into account: length, radius, heater power, and heating time.

In Fig. 2, the solid line shows the results of calculations of the temperature in the well, performed according to the developed mathematical model, and the measurement data shown by the triangles. It can be seen from the figure that the agreement between the theoretical and experimental data is quite satisfactory both in the heating mode and at the stage of cooling with liquid selection.

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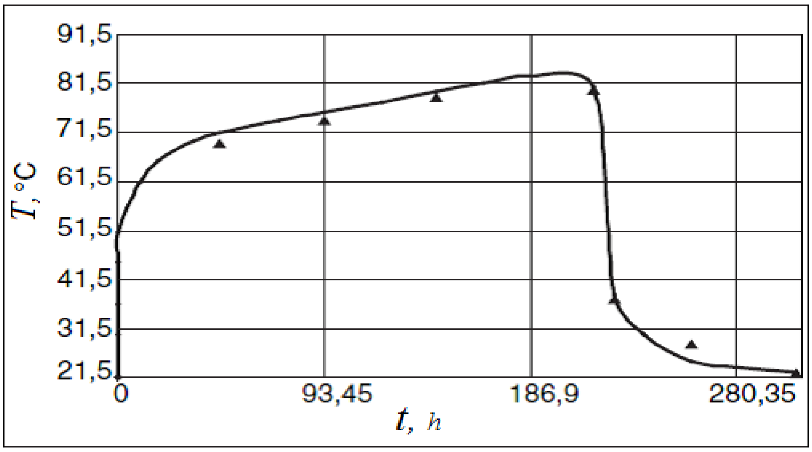

Figure 2: Comparison of temperature measurements in the well with the results of calculations

Thus, the proposed mathematical model and algorithm for calculating the main characteristics of the process of cyclic thermal impact on the bottom-hole zone can be used to predict field temperatures in the well and in the formation, as well as changes in the permeability of rocks.

Improving the reservoir properties of the formation due to its heating and decreasing the oil viscosity with increasing the temperature leads to an increase in well production.

Fig. 3 shows that in this example, the increase in the flow rate of the well, at the first moments of the well start-up, after warming up, occurs approximately up to 1.6 times. Then, over time, the flow rate tends to its initial value, if there are no irreversible changes in the reservoir properties.

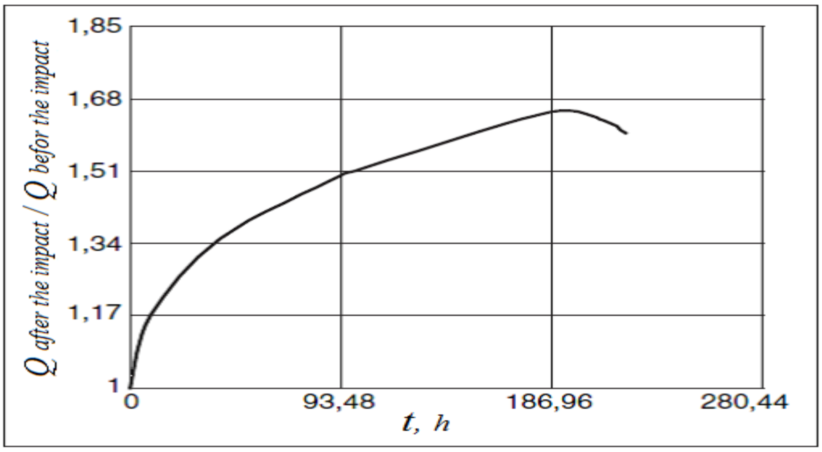

Figure 3: Change in the relative flow rate of the well over time

The “Bitumy” program allows predicting well performance as a result of thermocyclic heating. By changing the exposure modes, it is important to optimize the operation of the heating system. However, field studies conducted in oil fields have shown the need to take into account convective heat transfer. When the bottomhole zone of a shut-in well is heated, convective heat transfer along its wellbore can significantly reduce the effectiveness of thermocyclic heating. If the well is not shut-in during heating, then the radius of heating of the bottom hole formation zone is significantly reduced.

To increase the efficiency of the method and increase the heating zone, a new method of thermocyclic impact on the bottom-hole zone of the well was developed. The proposed method is as follows: in order to reduce heat losses associated with convective exchange of fluid in the wellbore, a thermal insulating sleeve (if necessary, a packer) is used, which is installed in the annular space at the level of the top of the bottom-hole formation zone (Fig. 4).

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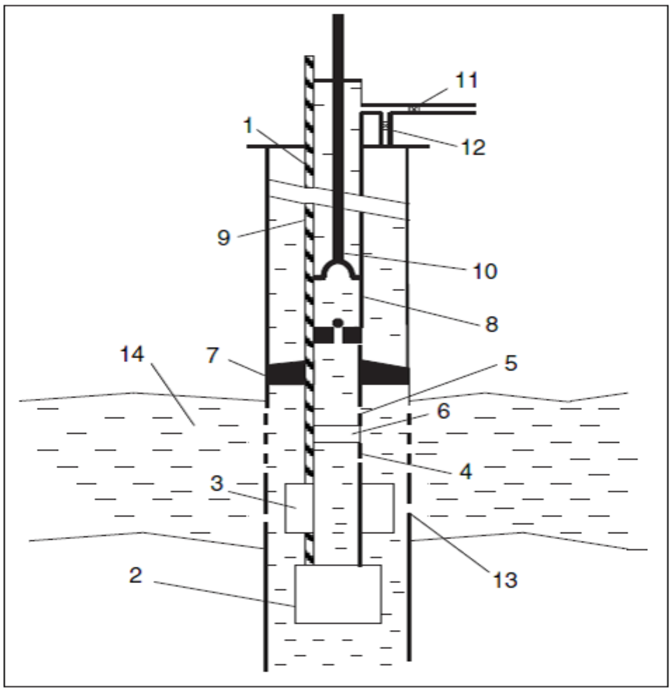

Figure 4: Layout of technological equipment for thermal cycling: 1 - tubing; 2 - electric submersible pump; 3 - electric downhole heater; 4, 5 - radial holes; 6 - heat insulating plug; 7 - thermal insulating collar (packer); 8 - deep rod pump; 9 - electric cable; 10 - sucker rods; 11, 12 - shut-off valves; 13 - perforations; 14 - reservoir

The thermal insulation sleeve is used to separate the heated part of the bottom-hole zone of the formation from the overlying part of the well.

This technology makes it possible to increase the efficiency of electric heating and increase the permeability of the bottom-hole zone of the formation.

Thermostatic cyclic heating allows processing the pay zone with the least heat loss and with the maximum depth of impact. Forced isolation of the heating area helps to reduce oil losses during the heating period.

III. METHOD PROCESSING

The essence of the method is as follows: after the installation of down-hole equipment (tubing, sucker rod pump, borehole electric heater and thermal insulation sleeve), the bottom-hole zone of the well is heated. In this case, the well is shut-in, and the well heater and the ESP (Electrical Submersible Pump) pump are turned on. When the ESP pump is switched on, the heated borehole fluid circulates throughout the space bounded by the thermal insulation sleeve. The heating time for each well is selected individually. After the heating, the well is started; the well heater and the ESP pump are switched off. The cycle repeats. The number of cycles depends on the formation lithology, daily flow rate of the well, effective reservoir capacity, oil viscosity and etc.

IV. CONCLUSION

As a result of using this technology, the heated bottom-hole zone will be cleared of paraffin deposits. In the cleared bottom-hole zone of the well, the effect of cyclic heating and cooling will be higher, since the radius of impact increases and the resulting microcracks will not be "sealed" as a result of paraffin deposition on their walls.

An increase in the permeability of rocks in the heating interval will contribute to an increase in the production rate of production wells, and when this technology is used in injection wells, an increase in their injectivity.

To increase the heating temperature to 200°C it is assumed to use a heater with an aluminum oxide coating. A high heating temperature will increase the amplitude of temperature fluctuations and the depth of the formation heating.

The use of a circulation pump will cover a significant range of pay zones with thermocyclic heating. The impact limitation will be determined by the different lithological properties of the layers.

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