Heating of heavy oil reservoirs using high-temperature heat agent recirculation

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Abstract. The prospects of using high-temperature heat for heating oil reservoirs are estimated. Considered one of the possible schemes of heat agent recirculation flow implementation. The conditions of the developed scheme practical using are analyzed.

1. Introduction
The demand for oil over the last decade, the world has increased significantly. However, light oil reserves diminish. Therefore, improvement of methods for heavy oil field development is an urgent task.

For the production of heavy oil methods of heat stimulation are promising. There are deposits of such occurrence and properties of the oil, in which the effects of thermal methods may be the only ones that allow development.

Most thermal stimulation methods based on the using of heat agents for heat transferring to the oil reservoir. The best heat agent among the technically possible - water and steam due to their high enthalpy. In general, the heat content of steam is higher than the water, but with pressure increasing benefits of steam are reduced, if they are assessed only in terms heat entered into the formation. This also indicates that the greatest efficiency is achieved when steam is injecting in shallow wells that require low pressures [1].

With steam injection occurs temperature front lagging behind the displacement front. However, due to the vaporization heat of steam condensation warmed reservoir area increases by 3-5 times (depending on the dryness of the injected steam, and pressure) as compared with injection of hot water [2]. This is one of the advantages of steam using as a heat agent. However, the use of steam with high pressure due to the lag of the temperature front from displacement front by 8-10 times increases the chance of a breakthrough in the production wells or aquifers. [3] With increasing temperature of the injected heat agent the efficiency of heating the reservoir increases, however, the use of superheated steam at a pressure of 2-3 MPa and a temperature of 400-500 °C for bitumen deposits does not provide sufficient warm-up, as at a pressure of 2 MPa and 400 °C, the enthalpy is 2834 kJ/kg, and at a pressure of 1.5 MPa and a temperature of 200 °C – 2792 kJ/kg [2], i.e. the values are almost equal. However, heating to a temperature of 400 °C and maintaining a pressure of 2 MPa requires equipment that is 2
times more expensive, and the cost of energy 1.5 times larger than a steam at pressure of 1.5 MPa and a temperature of 200 °C. There is a high risk of breaking the producing formation bottom, oil spills and steam on the surface of the ground or in the upper aquifers if shallow bedding of productive layers at injection pressure of more than 2 MPa [4].

Of particular interest is the use of high-temperature heat agent (HTHA) with temperatures ranging from 175 to 450 °C for heating the heavy oil reservoirs. HTHA advantage over other heat agents is the ability to use at high temperatures with noncritical pressures. To use the HTHA in practice necessary equipment providing HTHA supply with required parameters in the oil reservoir and realizing the coolant recirculation.

The aim of work is development of the implementation scheme of oil reservoir heating using HTHA.

2. Description of the scheme
Implementation scheme of oil reservoir heating using HTHA shown in Figure 1.

Figure 1. Implementation scheme of oil reservoir heating using HTHA: 1 - boiler; 2 - circulation pump; 3 - expansion tank; 4 – heat exchanger (in oil reservoir); 5 - heat exchanger temperature controller; 6 - heat exchanger pressure controller; 7 - process valves; 8 - measurement parameters of the boiler output (temperature, pressure); 9 - measurement parameters of the heat exchanger output (temperature, pressure)

HTHA flows from the expansion tank (3) into the circulation system. Then circulation pump (2) delivers the HTHA to the boiler (1) where HTHA is heated to the required parameters. Measuring devices (8,9) control HTHA parameters. The HTHA enters the heat exchanger (4) where it transfers heat to oil reservoir. After this HTHA through the circulation pump returns back to the boiler. Controllers (5,6) ensure the maintenance of the HTHA required parameters at the boiler outlet.

To preserve the physicochemical properties of HTHA and to preserve the possibility of its long-term recycling it is necessary to maintain the optimum temperature of coolant. Decreasing the maximum operating temperature of 10 °C increases the continuous operation time of the coolant about twice, therefore it is necessary to use HTHA with a maximum operating temperature of 20-30 °C above desired at the inlet of the heat exchanger.

To prevent the formation of scale on the inside of the pipes and for the enhancement of heat transfer it’s necessary to maintain high Reynolds number of HTHA flow. This will turbulize boundary
layer and reduce its thickness. It is proposed to use a boiler that ensure required parameters of the HTHA at its high speeds and minimum hydraulic resistance. The main objective of the creation high-speed boiler is to provide HTHA high speed in the heating surfaces in any capacity. Moreover, increasing capacity and increasing the thermal stress of heating surfaces the speed of HTHA in them increases and increases resistance to overheating and boiling. The task of ensuring HTHA high speed in the heating surfaces can also be solved due to circulation circuit consisting of circulation pump constant performance that connected to the supply line. The circulation pump provides increasing and maintaining the speed of HTHA in a closed circuit “boiler-pump-oil reservoir”. In addition, it is necessary to optimize the combustion process in the boiler furnace when fuel will be use associated petroleum gas [5-7]. This will greatly improve the energy efficiency of a heat transfer process.

3. Conclusion
The technological scheme of heating of an oil reservoir was developed. It is a closed circuit, which consists of a HTHA heating boiler, circulation pump providing recirculation of the coolant and a heat exchanger that transmits heat to the oil reservoir.

The recommendations for choice type of HTHA and the conditions of its movement were given. Recommendations will help to maintain the physicochemical properties of the coolant during prolonged recycling.

The work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

References
[1] Takhautdinov SH F, KHisamov R S, Ibatullin R R 2009 Neftyanoe khozyaystvo 7 pp 34-37
[2] Ibatullin R R 2011 Russia B. Tekhnologicheskie protsessy razrabotki neftyanikh mestorozhdenij 304
[3] Maksutov R A, Orlov G I, Osipov A V 2007 Neftyanoe khozyaystvo 2 pp 34-37
[4] Maksutov R A, Orlov G I, Osipov A V 2005 Tekhnologii TEHK 6 pp 36-40
[5] Saifullin E R, Vankov Yu V 2015 IOP Conf. Ser.: Materials Science and Engineering 86 012006
[6] Saifullin, E R, Larionov V M, Busarov A V, Busarov V V 2016 Journal of Physics: Conference Series 669 (1) 012037
[7] Saifullin, E R, Larionov V M, Busarov A V, Busarov V V 2016 Journal of Physics: Conference Series 669 (1) 012043