Effects of electrical and radio-frequency electromagnetic heating on the mass transfer process during miscible injection for heavy-oil recovery

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Electrical and electromagnetic heating can be considered as alternative to conventional thermal methods for the heavy-oil and bitumen recovery [1]. In certain circumstances, such as deep, tight or heterogeneous sand/carbonate reservoirs or oilshales, it is the only solution as steam injection cannot be applicable due to injectivity problems or high clay content [2]. For an efficient application of this relatively expensive technique and effective heat transfer from the source into the reservoir, optimal application conditions should be applied.

This paper deals with the effect of radiofrequency electromagnetic fields on mass and heat transfer processes in the multi component hydrocarbon system flowing in the porous media. The focus was on the clarification of the critical parameters affecting the recovery of multicomponent liquid (oil) under the influence of radiofrequency electromagnetic fields (RF-EM).

Experiments were conducted on solvent (kerosene) flooding of heavy oil under identical conditions. First the solvent flooding was carried out under radiofrequency electromagnetic field, then under electrical heating. The results were compared with the results of “cold” displacement, which is the base case with no inclusion of electrical or electromagnetic effects. The changes in the solvent concentration for all three cases are shown in Fig.1.

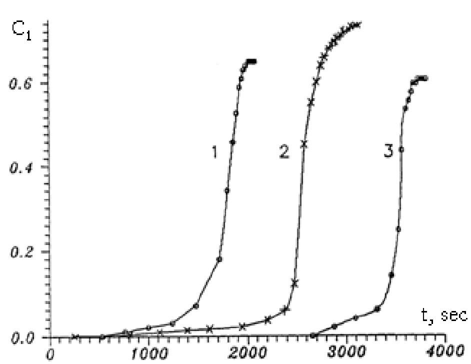

Fig. 1. The distribution of solvent concentration: 1 – “Cold” displacement; 2 – RF-EM field; 3 – electrical heating.

The data obtained from experiments were used to define the convective diffusion coefficients and oil recovery factor. In a multicomponent system under electromagnetic impact, there occur heat and mass transfer cross effects (thermodiffusion and electrothermodiffusion of an electromagnetic origin) [3].

Comparison of values of convective diffusion coefficients reveals that RF-EM field significantly accelerates the process of oil and solvent mixing (Fig. 1). This behavior shown in Fig. 1 clearly indicates that the effect of RF-EM is observed much earlier than that of electrical heating. But the progress of solvent is not as fast as in the case of electrical heating. Additional experimental evidence and mathematical modeling studies demonstrated that the main reason of this is the additional desorption of heavy components (paraffin-asphaltene-resinous substances and etc.) in case of the RF-EM case. This process reduces the recovery (or flow) rate for the RF-EM impact compared to the electrical heating case even though both experiments showed very close temperatures in the system.

The electromagnetic field influence on the residual oil recovery factor, however, was more critical and the highest recovery was obtained from the RF-EM case. This is attributed to the fact that the RF-EM field influences polar components of the oil, desorpting these components from the surface of the rock and add to the production. In other words, the RF-EM case was observed to be more effective than others in the recovery of heavier ends.

References

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