Review of the Scientific Advisor

for the dissertation thesis submitted on the Requirements for the Degree of Doctor of Philosophy (Ph.D.) in Petroleum Engineering (8D07202) Satbayev University

by **Sagyndikov Marat Serikovich**

titled **"Systematic Approach Investigation for Improving Polymer Flood Technology at the Kalamkas field"**

This is to certify that the doctoral student, Mr. Marat Serikovich Sagyndikov, has successfully fulfilled all the requirements needed for the Ph.D. degree conferment. His thesis title is "Systematic Approach Investigation for Improving Polymer Flood Technology at the Kalamkas field".

The relevance of the work

The majority of giant oil fields in Kazakhstan are entering or already in the brownfield development stage, and the Kalamkas oilfield is one of them. In view of the low reservoir temperature, elevated mobility ratio, and high formation permeability of the Kalamkas field, it was recognized that there is considerable potential for enhancing oil production by polymer flooding. For this reason, the Kalamkas polymer flood history started in 1981 and this project by scale and innovation was a pioneer in the Soviet Union. However, this effective EOR technology expansion was stopped due to the economic crisis. After 25 years of intensive waterflooding, tertiary polymer flood was considered to enhance oil recovery at the brownfield development stage. Although polymer flood is not novel technology for the Kalamkas field, Mr. Sagyndikov provided a number of valuable and relevant findings, which have tremendous practical applicability to improve polymer flood technology, confirming this dissertation's relevance.

The research results, their scientific novelty, and practical value

The objective of this dissertation was to investigate polymer flood at the Kalamkas field to develop a systematic approach for improving technology. Therefore, the research scope of this dissertation was focused on the following aspects: 1) A comprehensive literature review of recent worldwide polymer EOR projects focusing on the Kalamkas field polymer flood aspects; 2) Assess polyacrylamide solution chemical and mechanical stability during a polymer flood in the Kalamkas field; 3) Develop a novel method for the field assessment of polymer degradation during a polymer flood of an oil reservoir. 4) Experimental and numerical studies of the Kalamkas polymer flood technology. Examine the oil recovery at various simulation scenarios; 5) The Kalamkas polymer flood projects feasibility studies and choose the most rational scenario for full field deployment.

The scientific novelty in polymer solution stability studies is in field demonstration of the correctness of previous conceptual ideas— (1) that the vertical HPAM injection wells contained fractures that were necessary for polymer injection, (2) that the fractures substantially reduced mechanical degradation, and (3) that injected polymer solutions were quickly stripped of dissolved oxygen (thereby promoting oxidative stability). These demonstrations have value in countering arguments by others that polymer injectivity into vertical wells could be acceptable without fractures. This is the first published report demonstrating that backflowed HPAM samples from an injection well showed no detectable dissolved oxygen. Also, this is the first published report demonstrating that backflowed samples from an injection well showed no HPAM mechanical (or oxidative) degradation. Previous reports of produced HPAM samples (from production wells, observation wells, and back-produced injection wells) commonly noted substantial degradation—possibly, because of the sampling methods used. Thus, the sampling method reported here by Mr. Sagyndikov is also novel, important, and useful. These accomplishments are exquisitely

documented in his recent peer-approved paper "Field Demonstration of the Impact of Fractures on Hydrolyzed Polyacrylamide Injectivity, Propagation, and Degradation" in SPE Journal. – 2022. – Vol. 27, Iss. 2 – P. 999-1016 **(Q1 – 94 percentiles.)**

The Ph.D. student also developed a novel unconventional approach to model a polymer flood in the Kalamkas oilfield, which more objectively considers the behavior of the polymer solution in reservoir conditions. The results of these studies were published and reported at the prestigious International SPE Virtual Improved Oil Recovery Conference, which was held in the USA in April 2022.

The significance and practical value of the scientific results

Mr. Sagyndikov's work is critically important and relevant to the field application of polymer flooding. Without the field demonstrations in his thesis/work, substantial uncertainty would exist concerning whether the massive investment (tens to hundreds of millions of US dollars for large projects) in polymers for field polymer floods might be wasted due to either mechanical or oxidative degradation. The work by Mr. Sagyndikov appears highly reliable and complete. His several publications from this work will be highly valued by the petroleum industry wherever polymer floods are applied.

The reliability of the results is proved by the fact that they can be explained by the fundamental physics and chemistry laws, and do not contradict them.

Publication of Ph.D. thesis materials in print

The main hypotheses of the dissertation have been published in 7 articles, which include 1 – in the Scientific Journal cited in the Scopus base (Q1, 94 percentile), 2 – in the Scientific Journals listed in the recommended by the Committee for Quality Assurance in the Sphere of Education and Science of the Ministry of Science and Higher Education RoK, 3 – International Conferences, 1 – Patent for the utility model (KazPatent). Mr. Sagyndikov is the first author in all publications and affiliation shown as Satbayev University. Thus, Mr. Sagyndikov's work fully meets the requirements of the Satbayev University Dissertation Council.

In conclusion, the Ph.D. student has provided a high level of scientific research that is of high interest and contributes to the collective knowledge of the global community of petroleum engineers. Moreover, the work meets the requirements for the Ph.D. thesis. Therefore, I recommend that the author, Marat Sagyndikov, be allowed to defend his thesis because he deserves the Doctor of Philosophy (Ph.D.) in the specialty 8D07202 – Petroleum Engineering.

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