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"**

The presented Ph.D. thesis of Marat Serikovich Sagyndikov titled "Systematic Approach Investigation for Improving Polymer Flood Technology at the Kalamkas field" is devoted to increasing the efficiency of polymer flood for specific reservoir geological conditions and reservoir fluids properties of the Kalamkas field.

Field oil is heavy and highly viscous up to 20 cp in reservoir conditions. Formation water of Alb-Cenomanian horizon is used as the water source for polymer flooding, which chemical composition belongs to chlor-calcium type with total salinity of about 100 g/L. In 1981-1983 pure polymer solution was injected at the pilot area of the field. But the efficiency was low due to a number of reasons, in particular, increased salinity of injected water and reservoir geological heterogeneity. Due to this fact, during the next three years, periodical gel treatment with viscoelastic compositions of production and injection wells was performed, which decreased the watercut from 1,5% to 0,2-0,4% per month. Since the late 1980s, polymer flooding of the field has been stopped due to the economic instability of the former USSR.

Polymer flooding has been carried out in the field again since 2014, when the water cut reached 90%, and there was a noticeable downward trend in oil production levels.

The efficiency of polymer flooding largely depends on studying and solving the issues of mechanical and chemical degradation and other factors.

The relevance of the work. One of the directions for increasing the efficiency of oil displacement from reservoirs is increasing the displacing ability of water, first of all, by adding different chemical agents, in particular polymers. Although, in world practice, considerable experience of polymer flooding application is accumulated, in each specific case, the efficiency of this technology is influenced by specific geologic and physical characteristics and the current state of reservoir development, which requires an individual approach on which the success of the chosen technology depends.

In view of the above, the Ph.D. student devoted this work to the study of the systematic approach, which includes a complex analysis of geological and field data, laboratory research, fieldwork, numerical and analytical modeling, and feasibility studies to justify the optimal solution.

The work's objective is to justify polymer flood technology as a tertiary method to increase oil recovery for specific geological and physical conditions of the Kalamkas oilfield, characterized by high salinity of formation water and significant heterogeneity of reservoirs, assessing of chemical and mechanical stability of polyacrylamide solution, justification of new method of field assessment of polymer degradation during polymer flood, experimental and

numerical studies. The objectives also included analysis of predicted oil recovery under various modeling scenarios, feasibility studies, and selection of a rational scenario for full-scale commercial implementation.

The scientific novelty is to prove from field data that vertical injection wells contained fractures that were necessary for polymer injection and that fractures significantly reduced mechanical degradation and dissolved oxygen in the injected polymer solution (thereby contributing to oxidative stability). It should be noted that these were the first published papers proving that back-produced HPAM solution samples from an injection well showed no dissolved oxygen and also demonstrated the absence of mechanical (or oxidative) degradation of HPAM.

The main defending hypotheses:

1. Vertical HPAM injection wells contained fractures that were necessary for polymer injection. And these fractures substantially reduced polymer mechanical degradation.
2. Injected polymer solutions were quickly stripped of dissolved oxygen, thereby promoting oxidative (or chemical) stability.
3. At Kalamkas conditions, residual resistance factor (RRF) is not significantly different from unity, i.e., post chase water injection will not benefit oil recovery. Therefore, polymer injection should be underway as far as net present value (NPV) is positive.
4. Polymer flood at oil price volatility is a long-term project that extends the field's economically feasible lifetime and enhances oil recovery.

Implementation and Practical value:

A developed novel method for the field assessment of polymer degradation can be used to understand in-situ polymer EOR mechanisms better. Provided mitigation plan to eliminate chemical degradation that can save 25% of OPEX at the Kalamkas field conditions, thereby improving project economics. In addition, a novel approach to model polymer flood can be used to optimize polymer injection parameters, thereby improving technology efficiency.

Personal contribution. The dissertation's author contribution consists of the literature review, geological & reservoir dynamics data analysis, laboratory studies, field observations, and numerical & analytical modeling. The research results presented in the dissertation were obtained by the author personally or with his direct participation. Finally, the author formulated conclusions and recommendations.

Approbation and publications. The main results of the dissertation were reported and discussed at the following conferences and workshops: International Scientific Conference "Satbayev Readings – 2020" and "Satbayev Readings – 2021" (Kazakhstan, Almaty, April 2020 and April 2021); SPE Virtual Improved Oil Recovery Conference (USA, Tulsa, April 2022); Workshop organized by GazPromNeft "Chemical Enhanced Oil Recovery: challenges and prospects" (Russia, Kazan, June 2022). Furthermore, according to the results of studies obtained 1 patent for a utility model of the Republic of Kazakhstan, published 6 scientific articles, including 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.

Dissertation Organization. The dissertation is composed of six chapters. The introduction presents the general overview, relevance, objectives, hypotheses, and dissertation organization.

The total volume is 165 pages, including 55 figures, 27 tables, references of 168 titles, and 6 appendices.

The thesis is an independent completed work, the scientific results obtained by the thesis author make a significant contribution to the practice of improving the efficiency of oil field development.

In conclusion, by its relevance, the scientific and practical value dissertation work of Marat Serikovich Sagyndikov titled "Systematic Approach Investigation for Improving Polymer Flood Technology at the Kalamkas field" meets the requirements of the Committee for Supervision and Certification in Education and Science of the Ministry of Science and Higher Education. Therefore, the dissertation author deserves the Doctor of Philosophy (Ph.D.) in the specialty 8D07202 - Petroleum Engineering.

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