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Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Lyudmila Khakimova

PhD Program: Petroleum Engineering

Title of Thesis: NEW APPROACHES FOR NUMERICAL MODELING OF AIR-INJECTION BASED ENHANCED OIL RECOVERY

Supervisor: Associate Professor Alexey Cheremisin

Name of the Reviewer: Dmitry Eskin

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Signature:**  **Date: 11-11-2020**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications

The summary of issues to be addressed before/during the thesis defense

The doctoral thesis of Lyudmila Khakimova is dedicated to numerical modeling of air-injection based enhanced oil recovery (EOR) methods. The main focus of the research is simulations of the phase behavior and chemical reactions. The thesis is well structured and contains five chapters.

The thesis starts with the description of the subject background including an overview of existing problems of numerical modeling of enhanced oil recovery methods for different reservoir types, and a corresponding literature review. Within this chapter, the author formulates the investigation directions provides a summary of the problems, methods, and results for each of them.

The following chapters form the two parts:

1) development and validation of 3D laboratory-scale numerical models of high-pressure air injection (HPAI) and *in-situ* combustion (ISC) using existing simulators;

2) development of a novel approach for calculation of phase behavior in multicomponent multiphase hydrocarbon systems.

Laboratory and numerical method described in the first part of the thesis are presented in the second chapter.

The third chapter includes adaptation and history matching of ISC and HPAI laboratory experimental results for numerical modeling of air injection-based EOR for different reservoir types: medium oil in carbonates, bitumen, and organic-rich source rock

The fourth chapter is fully dedicated to the development of Gibbs (Helmholtz) free energy minimization algorithm for phase equilibrium calculations. This algorithm is extended to an arbitrary number of components and phases. Applicability of the algorithm developed for hydrocarbon mixtures is demonstrated by its validation against experimental results and comparison of the computed data with those obtained by flash calculations implemented in hydrodynamic simulators.

In the final chapter, the general conclusions are given. This section contains also a discussion and future plans.

The author has accomplished the research of a decent quality. I would appreciate if the author paid attention to the following comments:

Although, the text is clearly written, the author needs to attentively proofread it.

A few examples of minor typos and inaccuracies, which need to be fixed:

- Page 16. Please correct the format.
- Pages 21, 34, 43, 151. "Air injection-based EOR" should be substituted with "air-injection based EOR".
- Page 99. "…Small amount…" should be substituted with "…small number…".

Several figures could be improved:

- Figure 2.5: a plot in a vector format should be added.
- Figures 3.15-3.17: add "for carbonate oil field".
- Figures 4.10-4.14, 4.16: details are missing for different panels.

- The fourth chapter would sound better if the following subject is addressed. It would be worth to mention the initial application of successive substitution (SS) in flash calculations and its effect on the maximum number of iterations. Are there any known modern approaches to reduce CPU time spent on phase behavior calculations in commercial reservoir simulators such as INTERSECT?

Overall, the results obtained and presented by Lyudmila Khakimova are rather impressive. They are published in three international Q1 journals, and two reputable oil l& gas industry Russian journals. Taking into account that four additional papers, based on the thesis results are under review in Q1 journals, it is possible to conclude that Lyudmila noticeably exceeded formal Ph.D. thesis requirements.

Provisional Recommendation

☒ *I recommend that the candidate should defend the thesis by means of a formal thesis defense*

☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*

☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*