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Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Ms. Anastasia Gabova

PhD Program: Petroleum Engineering

Title of Thesis: Experimental Investigations of Thermal Properties of Unconventional Hydrocarbon Reservoirs at Formation Temperatures

Supervisor: Professor Yuri Popov
Co-supervisor: Dr. Evgeny Chekhonin

Name of the Reviewer: Sudarshan A. (Raj) Mehta, *PhD, P.Eng., Professor of Oil and Gas Engineering*

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Date: 02-01-2022**

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

Ms. Anastasia GABOVA's thesis entitled, "Experimental Investigations of Thermal Properties of Unconventional Hydrocarbon Reservoirs at Formation Temperatures," is generally well-written and acceptable with some editorial changes throughout the text. The thesis research project is aimed at development and application of a novel technique to measure thermal conductivity of organic-rich rocks from a number of unconventional "tight" reservoir formations in a temperature ranging from 30°C to 300°C.

Accordingly, a systematic experimental study to determine thermal properties including thermal conductivity, coefficient of linear thermal expansion (CLTE), volumetric heat capacity (VHC) of unconventional "tight" reservoir sample at elevated temperatures was carried out using a combination of divided-bar and optical scanning methods. This measurement technique for the thermal conductivity accounts for thermal anisotropy and heterogeneity of the rock samples and improves the quality of the experimental data. This approach overcomes systematic errors in the reported past measurements of oil shale samples using the divided-bar method and allows for the correction of measured results. It also enables accounting for the thermal contact resistance, non-parallelism of the rock sample surfaces, and changes in the rock sample structure during heating the sample.

In addition, the coefficient of linear thermal expansion (CLTE) of shale samples was studied using a quartz dilatometer, adapted specially for the measurement on standard core plugs. Strong correlations between the CLTE, thermal conductivity, and total organic carbon were established. For the first time, detailed profiles of CLTE along target wells were obtained using the optical scanning technique and established correlations between the thermal conductivity and CLTE. It was shown that these profiles fit well with total organic carbon obtained with pyrolysis. CLTE anisotropy was assessed for the target organic-rich shale samples along with thermal conductivity anisotropy. The new methodology for determining volumetric heat capacity at elevated temperatures for unconventional reservoir rocks yielded new relationship equations which relate thermal conductivity to temperature. The investigation involved 114 rock samples from seven (7) oilfields. This information, especially for organic-rich shales that exhibit significant thermal anisotropy and heterogeneity appears to be currently unavailable in the open literature.

Reliable data of the thermal reservoir rock properties are essential for heat flow density determination in enhanced oil recovery methods, basin and petroleum system modeling, wellbore stability analyses, and design of radioactive waste repositories. Nowadays, there is a lack of experimental data on thermal properties of organic-rich rocks at elevated temperatures and reliability of results is not provided.

The thesis consists of the well-balanced combination of relevant background, fundamentals and application of novel approaches to quantify the realistic and reliable thermal rock property measurements. It also highlights the complexities and challenges associated with the quantification the relevant thermal property data for "tight" unconventional reservoirs. The newly developed techniques for the thermal property measurements will be highly applicable and will contribute toward sustainable development and performance predications of "tight" unconventional hydrocarbon reservoirs.

It is clear that Anastasia has carried out a lot of original work which provides significant insights into the complexities and challenges associated with establishing thermal rock properties for "tight" unconventional reservoirs. I believe that she has made a good use of the existing literature. Her thesis, with minor editorial corrections, will be an excellent reference resource for future studies and applications.

Ms. Anastasia Gabova's thesis certainly satisfies the thesis requirements of her PhD program. Ms. Gabova has clearly demonstrated her capabilities of performing research work of high caliber. Presented PhD Thesis may be considered as complete qualification for a PhD candidate.

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*