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# Jury Member Report – Doctor of Philosophy thesis.

**Name of Candidate:** 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:** Dr. Irina Bayuk

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| I confirm the absence of any conflict of interest<br><br>(Alternatively, Reviewer can formulate a possible conflict) | **Date: 17-12-2021** |

*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**

This thesis is a comprehensive experimental study of thermal properties of unconventional hydrocarbon reservoir rocks under formation temperatures (30 – 300$^0$C). The studied rocks are from Bazhenov, Abalak, Mendym, Domanic, Sargaev, and Timan formations. The total amount of samples varies from 31 to more than 40 depending on the measured properties.

A necessity of these properties for the rocks is if vital importance due to the presence of organic matter (kerogen and bitumen) and fractures filled with formation fluids. The presence of organic matter is a reason of distinction of the thermal properties of these rocks (thermal conductivity, coefficient of linear thermal expansion, and volumetric heat capacity) compared to conventional hydrocarbon reservoir rocks. Thus, kerogen exhibits opposite behavior of its thermal conductivity and coefficient of linear thermal expansion compared to minerals – these values increase with temperature while for minerals they decrease. Besides, these rocks demonstrate anisotropy in the thermal properties that change differently with temperature in different directions.

The topic of the dissertation work is in relevance to its actual content. The methods and apparatus used for measurements of the thermal properties are suitable for the problems aimed to be solved in this work. Moreover, a combination of the optical scanning method with the divided-bar method commonly used in practice to obtained the thermal conductivity vs temperature allows the author to improve the accuracy of results on thermal conductivity measurements at formation temperatures. In turn, a combination of measurements of specific heat capacity and coefficient of linear thermal expansion makes it possible to obtain the volumetric heat capacity vs temperature.

The structure of the thesis is logical. First, the author discusses an actuality of the problem and formulates goals and objectives of the research (Chapter 1). Then, the author analyzes the state of art in experimental study of each thermal property and outline drawbacks and limitations of the approaches (Chapter 2). Then, the experimental methods used in the current research are described (Chapter 3). Chapter 4 presents the experimental results including the resulting correlation dependences for each studied thermal property on the temperature. Note that the correlation dependences derived by the author are of practical importance for estimating the thermal properties vs temperature for studied formations. An important result is that the dependences are different for different formations. Chapter 5 is the Summary and Conclusions.

The quality of publications is rather high. The author has 5 peer-reviewed papers in international scientific journals including those of Q1 (4 papers) and Q3 (1 paper) grade. The author has 1 Russian patent. The author also has 15 published expanded abstracts (some of them are cited in Scopus) related to the topic of the thesis which characterizes the author's activity at conferences.

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

(1) Page 19. The authors writes that the thermal conductivity is influenced by different factors including *anisotropy*. However, anisotropy is also a result (of rock composition and fabric) and not a reason.
(2) It would be helpful to show formulas for calculating the precision and accuracy of thermal conductivity measurements on standard materials (section 3.1.1.3).
(3) Page 44. I guess that the gradual correcting of thermal conductivity based on the results of optical scanning and divided-bar methods should be described in more details (page 44), step 6 of the algorithm.
(4) Page 50. Many different rock-physics approaches can be used to invert the cuttings' thermal conductivity from the thermal conductivity of mixtures, not only the two Licktenecker-based approaches that are commonly used just due to their simplicity. Some of the rock-physics method operate with the aspect ratio of particles (that have a clear physical meaning and could be experimentally estimated) instead of correction factors used in Licktenecker-based formulas.
(5) Page 52. The problem of determination of thermal conductivity of cuttings is non-unique since this is an inverse problem. I suggest to analyze a non-uniqueness of the inverted thermal conductivity of cuttings when applying the described procedure. By now, this is a recommendation for future work. However, this should be at least mentioned in the thesis.
(6) Data shown in Figure 15 are not clear. A disagreement with figure description in the text exists.

(7) Is the TOC provided by HAWK pyrolysis given in weight percent? Or this is in the volume percent?
(8) Figure 33. Please, clarify blue lines and numbers in the left figures.
(9) In the derived correlation dependences the units for all variables should be given.
(10) Figures 40 – 42. Please, indicate the sample direction.
(11) Page 116. It would be helpful to discuss the difference in the dependences obtained for the whole rock samples and cuttings prepared from the samples.

**Provisional Recommendation**

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

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| ☒ ***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* |