Review of the habilitation thesis

Title: Cryogenic Fluid Dynamics and Quantum Turbulence

Applicant: RNDr. David Schmoranzer, Ph.D.

The habilitation thesis is written in the form of a brief and concise explanation of selected phenomena related to low-temperature physics. The 10 papers published in renamed journals prove that the applicant becomes an important member of the research group leaded by prof. Skrbek and demonstrate his international activities. Scientific evolution of the applicant since his doctoral study is obvious. The subject of the habilitation thesis is much broader than that of applicant's doctoral thesis, which I also reviewed.

Three selected topics are addressed in the thesis, namely "Superfluidity and Quantum Turbulence", "Thermal Convection in Two-Phase Cryogenic Helium" and "Continuous Nuclear Demagnetization Refrigeration" respectively. Only essential findings and conclusions formulating hypotheses based on the results of series of experiments are presented. Most of the experiments were performed by applicant himself and his coworkers. Details are given in the attached papers relative to individual topics.

The most systematic and general part 1 on Superfluidity and Quantum Turbulence is subdivided into several subparts, 3 of them concern ^{4}He, the last one concerns ^{3}He-B. The adopted approach is based on model of the flows of normal and superfluid components of He, which are treated independently. The instability of the flow is studied using various means. Two types of instability in liquid He, namely classical hydrodynamic instability of laminar flow of the normal component and Donnelly-Glaberson instability in the superfluid component self-reconnections of quantized vortices upon reaching a critical velocity. Three critical velocity values were distinguished indicating various situations.

Drag exerting on bodies of different types is studied in oscillatory flow on the background of the flow instability involved. The Donnelly number was introduced, which characterizes well friction forces exerting on a submerged body, but fails in capturing instabilities.

The Prague group has been one of the first which has used quartz tuning forks to probe superfluid 4He successfully. This approach led, among other, to the description of the production of quantum turbulence, the detection of cavitation in both normal and superfluid helium, and to the observation of acoustic emission by the fork. The device serves to both generation and detection of turbulence in the same time. This two-fold role makes interpretation of measured results ambiguous, the additional theory is needed and offered by the authors.

The Particle Image Velocimetry method was adopted for the cryogenic application in its Tracking variant. Numerous technical difficulties including proper seeding and in the end correct physical interpretation of the obtained results have been addressed in the framework of applicant's research.

Temperature Inversion and Precipitation in Two-Phase Convection were studied in the other group of applicant's papers, physical mechanism of the phenomenon called "helium rain" is explained including its consequences.

The habilitation thesis is well prepared clear and systematic attesting the applicant's skills both in the experimental work in low-temperature physics and pedagogical field.

Extend of the applicants work documented by published papers attests broad activity field of the applicant. I appreciate applicant's active collaboration with several world renamed laboratories (Institut Néel in Grenoble, France, Lancaster University, UK, Aalto University in Espoo, Finland, B. Verkin Institute in Kharkiv, Ukraine).

The habilitation thesis contains new information and information adopted from the literature. The adopted information is cited in compliance with rules and ethics.

However, there is still an open space for future research activities, in my opinion.

In my capacity the submitted text **fulfils requirements** expected of a habilitation thesis in the field of low-temperature physics. I recommend acceptance the thesis and after successful defense to confer a title "docent" on the applicant.

Questions:

- The "quantum turbulence" is a different phenomenon than the "normal fluid turbulence", no doubt. The normal turbulence is defined by its attributes, which should be present in the flow to call it turbulent. Obviously, not all of them apply to the quantum turbulence. Could you formulate definition of the quantum turbulence and/or point out the differences between normal and quantum turbulence?
- What is the physical meaning of the Donnelly number? For the normal turbulence the Reynolds number determines the flow pattern for given boundary conditions. Donnelly number is a special form of the Reynolds number.
- In the experiments with the quartz tuning forks. What is the effect of the (low) temperature on mechanical properties of the fork material, in particular on its stiffness and internal damping? Is the temperature of the fork well-defined (i.e. homogeneous)?

In Prague, January 26, 2020

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