THERMOMECHANICAL EFFECT NEAR THE λ POINT IN ROTATING LIQUID HELIUM[1)]

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Submitted to JETP editor August 6, 1963

J. Exptl. Theoret. Phys. (U.S.S.R.) **46**, 162-164 (January, 1964)

The temperature dependence of the fountain effect in rotating He II shows that rotation does not cause a shift of the λ-point in the region 2.17—2.23°K, where reported hydrodynamic experiments [3] detected the presence of vortex effects.

In rotating liquid helium, the phase transition at 2.17°K shows certain special features. Thus, for example, the quantized Onsager-Feynman vortices are formed, with a certain delay, during the smooth transition from rotating He I to rotating He II. [1] The Andronikashvili vortex characteristic of a boiling classical fluid under rotation survives for a substantial period of time in He II as well. [2] In the inverse case of a transition from rotating He II to rotating He I the Onsager-Feynman vortices persist above 2.17°K. [3] It is natural to think that we are dealing either with a modification of the phase transition as compared with that for the stationary liquid, or with a rotation-induced shift in the λ-point.

As is well known, the thermomechanical effect occurs only in a superfluid liquid. If, at a smooth transition from rotating He II to rotating He I, the rotation causes a displacement of the λ-point toward higher temperatures, we should be able to observe a fountain pressure even above 2.17°K. The thermomechanical effect was first employed for investigating the properties of rotating He II by Andronikashvili and Kaverkin. [4] On the basis of their observations, these authors reach the conclusion that not only does the phenomenon of superfluidity not vanish under rotation but also that its quantitative characteristics remain unchanged (i.e., the ratio ρ_n/ρ). Near the λ-point, however, this conclusion may not be correct, and thus requires special verification.

A cylindrical beaker of transparent plastic (see Fig. 1), 1.25 cm in radius and 10 cm high, was so arranged as to rotate about its central axis. A glass capillary of 1.9 mm inside diameter containing a tightly-packed plug of rouge was mounted coaxially within the beaker. An electrical heater of 50 μ constantan wire was placed above the plug.

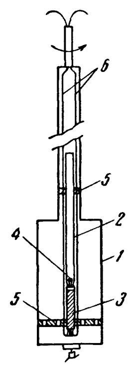

FIG. 1. Apparatus diagram: 1—transparent plastic beaker, 2—glass capillary, 3—rouge plug, 4—electrical heater, 5—spacers, 6—wires carrying voltage to the heater.

The heater was supplied with a stabilized direct current through mercury ring contacts located on the Dewar cover. The wires supplying the voltage to the heater passed through the hollow, grease-packed German silver drive shaft of the system. The power supplied was regulated by means of a sensitive electrical circuit made up of wire-wound rheostats. Voltage and current were measured with the aid of class 0.5 laboratory instruments. The apparatus was illuminated by a daylight lamp through slits in the Dewars.

The experiment was carried out in the following manner: the liquid helium was cooled to 1.4°K by pumping on the superincumbent vapor. The system was then set into rotation. The presence of a fountain effect was checked by turning on the heater. Pumping was then stopped, and the liquid temperature rose gradually to 2.2°K. As the temperature approached 2.17°K, the thermomechanical effect was observed to be present in every case before the temperature reached the λ-point, but was never observed after the λ-point had been passed. The approach to the λ-point could be gauged by the rapid increase in the pressure indicated by a differential oil manometer.[2)]

[1)]Presented at the X All-Union Conference on Low Temperature Physics, Moscow, 1963.

[2)]It should be remarked that the Onsager-Feynman vortices were observed to survive the transition from rotating He II to rotating He I for a period beyond that required for the oil manometer to respond to the passage through the λ-point.

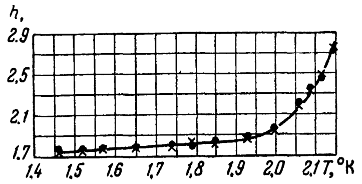

FIG. 2. Temperature dependence of fountain column height in stationary (●) and rotating (x) helium. Angular velocity $\omega_0 = 26.1\ \mathrm{sec}^{-1}$. Power dissipated in heater W = 4.0 mW. Height h in cm of helium.

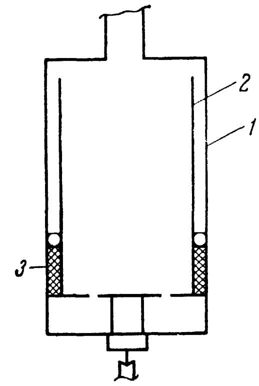

FIG. 3. Schematic representation of second apparatus: 1—outer cylinder, 2—inner cylinder, 3—electrical heater.

Thus, the thermomechanical effect is not present in rotating helium above the λ-point, even in its immediate vicinity. Consequently, no displacement of the λ-point towards higher temperatures takes place as a result of rotation.

The data presented in [3] show that, beginning at 1.9°K, the observed damping in rotating He II lies above the theoretical curve. As the temperature increases the separation between the two curves becomes greater. In order to resolve the question of whether rotation adds a similar contribution to the thermomechanical effect, especially as the temperature increases, we recorded the temperature dependence of the fountain column height with the helium both at rest and rotating at $\omega_0 = 26.1\ \mathrm{sec}^{-1}$ [3)]. Readings were made on the helium level in the capillary with the aid of a model KM-6 cathetometer. As can be seen from Fig. 2, the data from the experiments with both stationary and rotating helium lie closely along a single curve over the whole temperature range investigated.

In view, however, of the recently demonstrated possibility of the formation near the rotational axis of a region free of vortex lines, [5] the measurements just described may refer only to the region in which the vortex lines are absent; as a consequence, a "λ-point shift effect" may have escaped our attention. For this reason we undertook an experiment in which the fountain effect was observed in the annular gap between the coaxial cylinders 1 and 2 (Fig. 3). Both cylinders rotated about their common axis. The lower portion of the gap was plugged about its whole circumference with rouge. An electrical heater was placed above the rouge plug. The use of this apparatus yielded results in complete agreement with those obtained with the previous system.

It has thus been shown that under the conditions prevailing in our experiments no superfluid component exists at temperatures above 2.17°K (which corresponds to the λ-transition in stationary He II), even in its immediate neighborhood, and that the presence of the excess vortex damping observed in the temperature range 1.9—2.23°K [3] must therefore be ascribed to relaxation effects.

The authors regard it a pleasant duty to thank É. L. Andronikashvili for suggesting this problem, for helpful discussions, and for his interest in this work.

[3)]Andronikashvili and Kaverkin[4] measured the thermomechanical effect in stationary and in rotating helium at only three temperatures; it is therefore impossible to plot the thermomechanical effect as a function of temperature from their results.

[1] Andronikashvili, Tsakadze, and Bablidze, JETP **43**, 1562 (1962); Soviet Phys. JETP **16**, 1103 (1963).

[2] D. S. Tsakadze, JETP **44**, 105 (1963), Soviet Phys. JETP **17**, 72 (1963).

[3] Andronikashvili, Mesoed, and Tsakadze, JETP **46**, 157 (1964), this issue, p. 113.

[4] É. L. Andronikashvili and I. P. Kaverkin, JETP **28**, 126 (1955), Soviet Phys. JETP **1**, 174 (1955).

[5] M. P. Kemoklidze and Yu. G. Mamaladze, JETP **46**, 165 (1964), this issue, p. 118.

Translated by S. D. Elliott
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