DIRECT MEASUREMENTS OF THE LINEAR FLOW RATE OF A He II FILM

B. N. ESEL'SON, Yu. Z. KOVDRYA, and
B. G. LAZAREV

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ONE of the most important characteristics of a superfluid helium film is its flow rate and the dependence of this rate on the temperature. However, the overwhelming majority of experiments on the He II film yield the transport rate, which is the volume of the fluid flowing in one second through 1 cm of the film perimeter. Since this quantity is the product of the linear speed of the film by its thickness, one can obtain information also about the linear flow rate of the film from data on the temperature dependence of the film thickness.

The values obtained in the indicated manner[1,2] lie in the range 20—37 cm/sec at 1.5° K. More detailed information is contained in the paper by Jackson and Henshaw[3], who used the same method for the linear flow rate and obtained values of 66—104 cm/sec at temperature variations from 1.1 to 1.9° K. However, since the transport rate in these experiments was twice as large as the one usually registered under the same conditions, the information on linear transport rate raises naturally, some doubts[4].

In other experiments[5] information on the linear film flow rate has been obtained by studying the formation of liquid drops from the film on coils of various lengths. The measured speed proved to be 18 cm/sec at 1.3° K.

Since there is as yet no sufficiently detailed information on linear flow rate and formation of the He II film, experiments of the following character have been conducted.

The apparatus (Fig. 1) comprised a rod and a helix 6 made of glass tubing of 5 mm diameter and joined together at the base, was suspended on a filament in a helium cryostat, and could be displaced in the vertical direction. The length of the rod was 9.5 cm, and the helix had an inside diameter of 7 mm and 12 turns. The upper ends of both the rod and the helix terminated in thin-walled copper transition pieces on which were wound resistance thermometers 4 and 5 made of lead brass. The thermometers were identical, and had a resistance of about 0.5 Ω at 1.5° K. The device described could be brought in contact with the liquid He II contained in glass vessel 3 situated in a dewar with liquid helium. This provided good screening and the temperature gradient in the gas phase was decreased to a considerable degree.

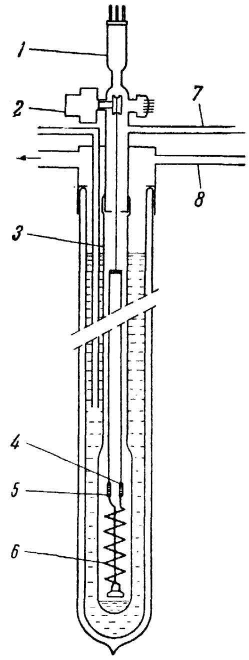

FIG. 1. Apparatus for measurement of the linear flow rate of a helium film.

When contact was made between the suspended device and the liquid helium in vessel 3, the He II film flowed toward the thermometers on both the rod and the helix. At a measuring current of 10 mA, the thermometers located in the gas phase prior to the contact were about 0.05° warmer than the liquid helium. Therefore the onflow of the He II film cooled the thermometers, whereby the corresponding change in potential difference amplified by a two-channel amplifier could be registered with a loop oscillograph. Since the paths of the film thermometers 4 and 5 differed substantially from one another, the film reached the thermometers at different instants. This time interval was determined from the bends in the plot of the potential difference against the time, as registered by the oscillograph. Knowing the path difference corresponding to this time interval it was possible to obtain the values of the linear flow rate of the helium film.

Experiments of the indicated character were conducted in the temperature interval 1.50—2.13° K. It must be noted that the value of the smallest distance along the internal surface of the helix was used in calculating the linear rate (the path difference of the film along the internal surface of the helix and along the rod was 16.9 cm). Special experiments showed the absence of influence of the thermometers on each other and the absence of a noticeable temperature gradient in the gas phase.

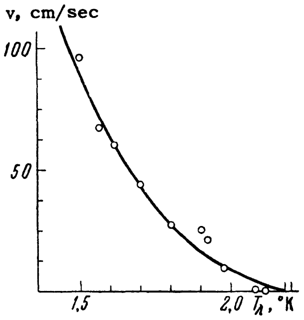

FIG. 2. Dependence of the linear flow rate of a helium film on the temperature.

During the experiment the temperature was maintained constant with an accuracy of 10^{-5} deg by an electronic stabilizer[7]. The results obtained are given in Fig. 2, which shows the temperature dependence of the flow rate of the helium film.

As is seen from the figure, the linear flow rate of a He II film increases with decreasing temperature and reaches about 100 cm/sec at 1.5° K. This surpasses considerably the critical value calculated from known values of the transport rate and film thickness[1,2] as well as the results obtained in [5]. However, it must be noted that in these investigations the stationary flow of the helium film was studied, while in the experiments described above the speed values obtained refer to the flow onto a surface free of helium. It follows from this that under such conditions the film flow rate may surpass considerably the stationary flow rate. This circumstance agrees with measurements of the thickness of a helium film flowing onto a developed surface made by Kikoin and Lazarev[6].

Such large values of the flow rate of a helium film are possibly explained by the fact that during the time of the film flow (about 0.2 sec at 1.5° K) vortices do not have time to develop strongly enough and consequently to produce friction forces to slow down the film. It is also not excluded that the circumstance that the film must form a normal component as it moves may play a certain role in these phenomena. The experiments conducted at present will probably help to obtain more detailed information on this interesting question.

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STANDING MAGNETOPLASMA WAVES IN BISMUTH SINGLE CRYSTALS

M. S. KHAĬKIN, V. S. ÉDEL'MAN, and R. T. MINA

Institute for Physical Problems, Academy of Sciences, U.S.S.R.; Physics Institute, State Atomic Energy Commission, Erevan

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THE possibility of propagating electromagnetic waves in a metal located in a strong magnetic field has been considered theoretically by Konstantinov and Perel'[1] and by Skobov and Kaner,[2] who showed that slightly damped waves may be propagated under the following conditions: that the Larmor radius is smaller than the wavelength in the metal, that the Larmor frequency is higher than the wave frequency, which is in turn much higher than the collision frequency. The latter condition ($\omega\tau \gg 1$) essentially distinguishes these waves, which we shall call magnetoplasma waves, from magnetohydrodynamic Alfven waves ($\omega\tau \ll 1$).

Indirect proof of the existence of magnetoplasma waves of microwave frequency in bismuth has been obtained by several authors.[3-6] The excitation of low-frequency magnetoplasma waves has been observed in several metals[7-10] having about one electron per atom (the term "magnetoplasma resonance" was introduced in [8]). Very recently there appeared a brief communication by Kirsch[11] on the observation of standing waves in bismuth for the case $\mathbf{H} \parallel \mathbf{N} \parallel C_2$ (i.e., P-waves, see below).

Some results of a detailed investigation of microwave-frequency magnetoplasma waves, excited