LINEAR FLOW RATE OF FILMS OF HELIUM ISOTOPE SOLUTIONS

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The temperature and concentration dependence of the linear flow rate of films of He^3-He^4 solutions was investigated in the temperature interval between 1.5° K and T_λ and for concentrations of from 2 to 16% He^3. The values obtained for the linear speed substantially exceed those computed from data available in the literature on the mass flow rate and film thickness. This discrepancy apparently can be explained by the influence of vortices on the film flow rate.

GENERALLY the phenomenon of transport by a film of helium II is characterized by a transport rate which is the product of the film thickness times the linear speed of motion. A large amount of work has been devoted to the study of the transport rate for He^4 and the influence on it of different factors (temperature, different levels, substrate material, etc) which have allowed the establishment of the fundamental relationships of this phenomenon[1]. Similar information, although less detailed, has been obtained for films of He^3-He^4 solutions[2-4].

Despite the fact that information about the linear speed of motion of a film can be obtained from this by the use of the known values of the film thickness, a direct experimental determination of the linear speed is nevertheless extremely desirable and of great interest. The first results of such experiments[5], performed with He^4, revealed that a film flowing onto a "dry" surface has a linear speed which significantly exceeds the value calculated by the above means and has a different temperature dependence.

In this connection, the performance of experiments with mixtures of He isotopes seemed feasible. The methods of measurement of the linear flow rate of a film were similar to those used in [5]. The essential part of the apparatus was two 3 mm diameter glass rods which had a common base and had resistance thermometers attached to them (lead brass with 0.05 mm diameter). The thermometer arrangement was as follows: one was on the first rod at a distance of 5 mm from the base, the second was on the second rod at a distance of 85 mm from the base; the interval between thermometers comprised 80.87 ± 0.01 mm. Such an arrangement could be moved in the vertical direction inside the container in which the He^3-He^4 mixture was condensed. The system was shielded from thermal radiation with special baffles. The temperature in the surrounding helium bath was maintained constant within 10^{-5}° K with the help of an electronic stabilizer.

When the base of the described device was brought in contact with the surface of the liquid the film moved along the rod, reaching the thermomenters at different moments of time. Provided that the thermometers were overheated relative to the bath by a few hundredths of a degree, as soon as the film reached them the thermometers were cooled and correspondingly they changed their resistances. The changes of potential difference were amplified by a two-channel direct-current amplifier and were recorded with a loop oscillograph (9SO-1F2). From these oscillograms it was possible to determine the time interval (with an accuracy of 0.01 sec) corresponding to the traversal by the film of the distance between the thermometers which in turn enabled us to calculate the flow rate of the film.

Experiments were conducted with helium isotope solutions whose concentration, owing to the large volume of the gaseous phase, varied with changes of the temperature. Monitoring over changes of concentration was accomplished by means of the measurement of the vapor pressure over the solution. In the interval of temperature investigated (1.5° K to T_λ) the concentration x of the solutions used was varied in the following range:

Solution	A	B	C	D
x, % He^3:	2.1—2.8	4.2—4.6	7.9—8.9	15.3—16.3

The obtained results are presented in Fig. 1 in

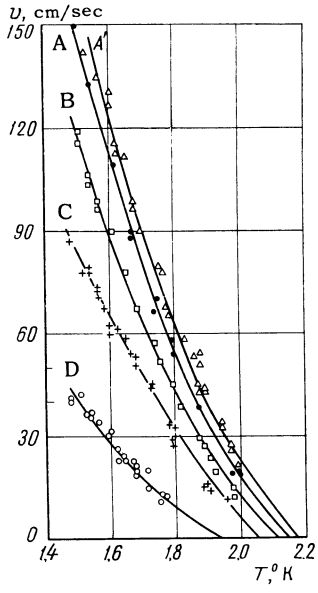

FIG. 1. Temperature dependence of the linear flow rate of a film of helium isotope solutions.

which the temperature dependence of the linear speed is plotted for the indicated solutions and for pure He^4 (curve A').[1)] It is clearly seen that the film's linear flow rate increases rapidly with decreasing temperature both in the case of pure He^4[2)] and in the case of He^3-He^4 solutions. The measured values substantially exceed the values calculated from experiments on the observation of steady-state flow of a film[1].

With an increase of He^3 content in the solution, the film's linear flow rate decreases (Fig. 2) and associated with that is a decrease in concentration of the superfluid component. It may be inferred that film flow with such high speed necessarily always occurs in the initial period of migration. However, the detection of this phenomenon has been lacking until the present time. The phenomenon probably is to some extent responsible for the high transport rate generally observed when the helium level is near the edge of the ampoule[6].

[1)]The maximum deviation from the mean value was 10% but the root-mean-square deviation was 4.6%.

[2)]The values obtained in [5] for the linear flow rate of He^4 film were smaller than in the present work; this can be attributed to the dependence of the flow rate on the length of path traversed by the film.

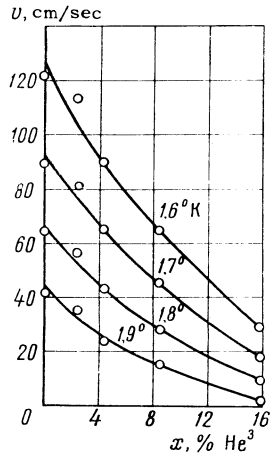

FIG. 2. Dependence of the linear flow rate of a film on the concentration of He^3 at different temperatures.

The present results enable us to draw a conclusion: Both for He^3 and for He^3-He^4 solutions the flow characteristics along the "dry" surface and in the steady-state case are greatly different from each other. A possible reason for this, as already mentioned[5,7], is the differences of generation mechanisms for vortices in a film, which change its velocity.

Experiments now under way probably will enable us to obtain new characteristics of this phenomenon.

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