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VISCOSITY MEASUREMENTS IN SUPERFLUID ^3He -B TO 1 mK.

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Résumé.- Nous avons mesuré la viscosité dans la phase B de ^3He à l'aide de deux techniques différentes utilisées en parallèle. Dans un cas, il s'agit d'un oscillateur de torsion, dans l'autre d'une corde vibrante. Ces deux méthodes sont en désaccord frappant avec d'autres résultats expérimentaux obtenus précédemment et avec la théorie actuelle. Nous avons observé une décroissance monotone de la viscosité jusqu'à la limite inférieure de température que nous avons pu atteindre, soit 1 mK. Cet effet est encore plus prononcé à des pressions plus basses.

Abstract.- Viscosity measurements in the B phase of ^3He have been made using two different devices simultaneously. One was a torsional oscillator and the other was a vibrating wire. Both methods show a striking discrepancy with earlier measurements and with existing theory. We observe a monotonic decrease in the viscosity down to the lowest temperature reached, 1 mK. This effect is more pronounced at lower pressures.

The viscosity of the normal component in superfluid ^3He -B has been investigated by a variety of techniques often resulting in seemingly contradictory results. Early measurements on the melting curve using a vibrating wire viscometer indicated a rapid decrease in the viscosity upon entering the A phase; followed by a plateau (seen for both A and B phases) in the reduced temperature regime, $0.92 \geq T/T_c \geq 0.58$; and at the lowest temperatures, a rise in the B phase viscosity [1]. Off the melting curve, but restricted to higher temperatures, viscosity values derived from hydrodynamic heat flow experiments qualitatively supported the plateau behavior [2]. More recently, torsional oscillator measurements, on an annular volume of ^3He [3] and on samples confined by parallel plates [4] have indicated slow monotonic decreases in the normal component's viscosity in the same temperature regime that the earlier measurements showed levelling off. Again, however, all these measurements were restricted to temperatures near T_c .

In an attempt to clarify these results and to extend viscosity measurements to lower temperatures with a broader pressure range, we have cooled two viscometers a vibrating wire similar to the earlier Helsinki design and a torsional oscillator in which the ^3He sample is confined to a disk shaped volume, by using nuclear demagnetization. Our results from both devices indicate that the viscosity continues to decrease with no indication of leveling off to the lowest temperatures reached. The temperature of the ^3He probed by the two viscometers is determined by the nuclear susceptibility of Platinum powder using

pulsed NMR.

The torsional oscillator was similar to one used by Parpia et al [4]. The ^3He was confined to a disk shaped region with a height of 95μ and a radius of .42 cm. A BeCu tube suspended the epoxy enclosed ^3He and acted as fill lined and torsion rod. The device was driven and its motion detected, electrostatically. Details of the design and analysis can be found elsewhere [5]. In terms of the two fluid model for characterizing the superfluid hydrodynamics, the oscillator measured the density and viscosity of the normal fraction of the superfluid. Normal component density measurements are reported in another LT 15 paper.

The vibrating wire viscometer sampled the same ^3He reservoir as the torsional oscillator. The wire was a Formvar coated, copper clad NbTi wire with a diameter of 0.3 mm. Securely held at both ends, the wire was centered in a cylindrical geometry with length 2 cm. and diameter 0.25 cm. A superconducting coil wound lengthwise around the sample volume provided about 0.3 Tesla transverse to the wire axis. The wire was driven by an AC current source at the resonant frequency of the wire plus surrounding ^3He fluid, 3100 Hz. While the empty cell Q was quite high (10 000), in the presence of the ^3He , viscosity induced dissipation reduced the Q to between 20 and 100. Using a biphasic lockin amplifier in signal tracking mode, the wire was allowed to self-resonate

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with a constant drive level.

In principle, simultaneous measurement of the resonant frequency and the induced voltage across the wire which measures the wire motion should be possible and from such, determination of the density and viscosity of the normal component could be extracted. In practice, however, the broadness of the resonance, and the time lag in following the frequency changes of the resonance, a consequence of the necessary integration of the signal to remove noise, prevented accurate frequency measurement. However, as confirmed by normal liquid measurements, the amplitude of the response was an accurate measure of the Q of the wire. In order to take full advantage of the highly resolved oscillation amplitude measurement we ignore the frequency shift information and instead use the normal fraction density measurements from the torsional oscillator. Details of this analysis will be presented elsewhere.

Figure 1 shows our results for the viscosity as measured by the two viscometers.

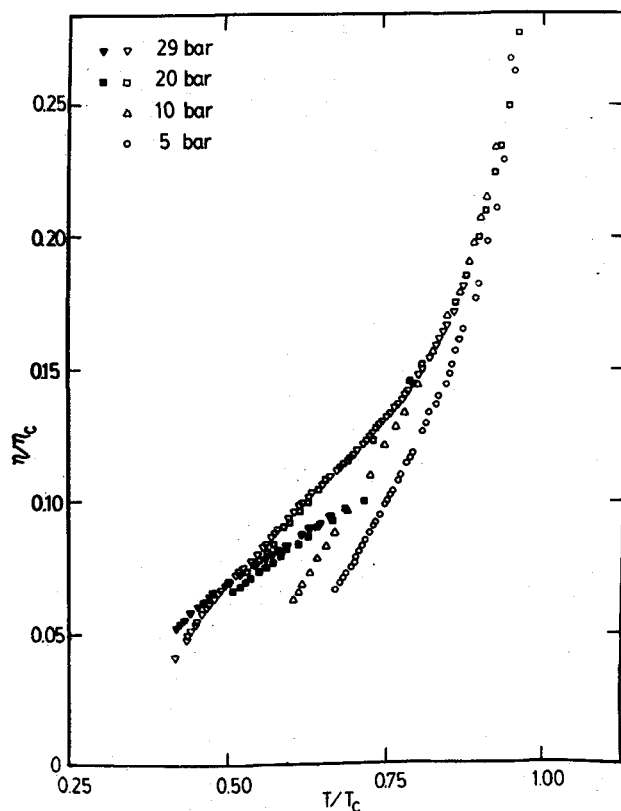


Fig. 1 : Viscosity normalized to the value at the transition, η/η_c , versus reduced temperatures, T/T_c . Open symbols are from the torsional oscillator ; closed symbols, the wire viscometer.

The rapid decrease near T_c in the torsional oscillator results is qualitatively as expected and has been precisely measured in a similar device using the higher resolution of a CMN thermometer /4/. We restrict our attention to the region below $T/T_c \approx 0.9$. We observe no leveling off of the viscosity as reported earlier. Significantly, the vibrating wire, with dimensions similar to the earlier Helsinki design, also shows a monotonic decrease. The wire results are restricted in their pressure and temperature range due to the suppression of the B phase in a magnetic field.

In contrast to the results reported here, theoretical work predicts a plateau region for the viscosity at intermediate temperatures followed by a gradual rise to a zero temperature value approximately one-third the transition temperature viscosity /6,7/.

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