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An Experiment to Measure the Effect of Magnetic Fields on the Superfluid Fraction and Transition Temperature of ^{3}He in Aerogel

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We present preliminary results from a torsional oscillator experiment designed to measure the superfluid fraction and transition temperature of ^{3}He in aerogel in magnetic fields up to 0.4 T.*

1. INTRODUCTION

Experiments on pure superfluid ^{3}He in aerogel have shown that aerogel is an interesting and unique system in which to study ^{3}He. The experiments, which measured the superfluid via superflow [1] and NMR [2], have raised many questions about the nature of the superfluid in aerogel and have spawned several theoretical papers to address these questions.[4, 5] Clearly the next step in studying the system experimentally is to probe the system with other techniques (heat capacity, sound, etc.) and to explore some of the adjustable parameters besides pressure and temperature which are available (magnetic field, ^{4}He concentration, superflow velocity, etc.). In this paper we describe an experimental cell designed to measure the superfluid in a magnetic field with a torsional oscillator, and some of the preliminary results obtained with the cell. The experiment was motivated by preliminary NMR results [6] on the ^{3}He/aerogel system in different magnetic fields. Since our experiment measures the macroscopic superflow within the cell at different fields and flow amplitudes, it is very complementary to studies using NMR at different fields and zero flow, and together the two experiments should help constrain possible theories for the system.

2. THE CELL

The cell we have made is very similar to previous torsional oscillators, with a few exceptions. The torsion rod and heat exchanger body are made of coin silver (~ 10% copper) in order to decrease the heat capacity of the cell in a field. The electrode support structure is made of magnesium for the same reason and because of the ease of machining it. Titanium screws were used to bolt the heat exchanger to the torsion rod flange and the electrode support structure to the cell. In addition, the aerogel was grown directly into a pure silver cup instead of a stainless cup[3]. The cell is placed inside a partially compensated magnet which we wound to have a bore of 2.8 cm. The magnet produces a field of 880 gauss/Amp, and is capable of storing 5 Amps, for a maximum field of ~ 4 kgauss. The oscillator is run in a con-

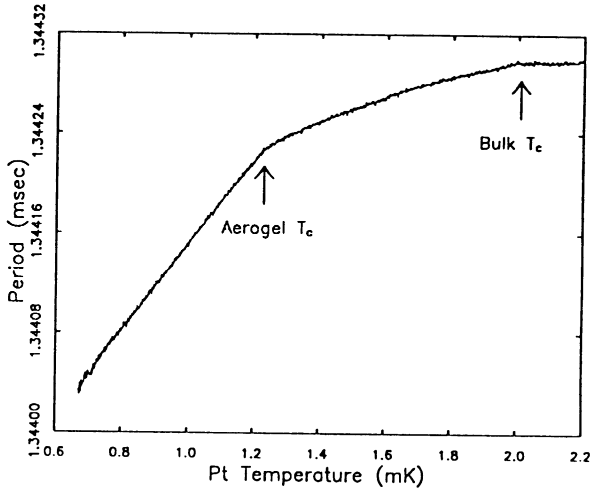

Figure 1: Period of the oscillator while cooling, at a pressure of 13.7bar, and a field of ~0 gauss.

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stant amplitude phase locked loop. A platinum NMR thermometer and melting curve thermometer are attached to the stage of the cryostat. The present design does not include a thermometer internal to the cell, but one is under construction.

Unlike the cell we have used to study pure ^{3}He in zero field [1], this cell had a significant signal due to the presence of bulk ^{3}He. This bulk signal turned out to be useful, since the bulk superfluid transition could be used as a fixed temperature point inside the cell. The bulk fluid contributes to the period shift in the normal and superfluid state. In the normal state the period shift increases and the dissipation decreases when cooling from ~100 mK. This "locking up" signal is due to the $\sim T^{-2}$ increase in the viscosity of ^{3}He. At temperatures at and below the superfluid transition, the fluid is always in the well locked limit, and the subsequent period shift is a measure of the superfluid density.

3. DISCUSION

Thermal gradients between the nuclear stage and the experimental cell preclude us from making any quantitative measurements of the effect of an applied magnetic field at this time. A viable experimental configuration which includes an internal thermometer is under construction. With the current apparatus we have demonstrated that we can operate the oscillator in fields up to 3 kgauss, and we can clearly see the bulk and aerogel transition.

An example of the period of the oscillator obtained while cooling is shown in figure 1. The bulk superfluid transition is signaled by the first change in the slope of the period. Well below the bulk transition the second change in slope signals the aerogel transition. We have measured the period shift of the oscillator at 13.7 bar in 0, 875, 1750 and 2640 gauss. Under the assumption that the bulk B-phase superfluid fraction temperature dependence is only weakly modified by a magnetic field, we can use the bulk period shift to measure the suppression of the aerogel T_c. The bulk superfluid fraction at the onset of superfliudity within the aerogel appears to be identical for all fields. We find a similar field independance for the onset of the aerogel T_c at 20 bar in fields of 875 and 1750 gauss.

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[6] The aerogel sample had a porosity of 98.2%. It was kindly grown for us at Penn. State by N. Mulders in M.H.W. Chan's research group.