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STRONG COUPLING EFFECTS AND THE NORMAL FLUID DENSITY OF LIQUID ^{3}He-B

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We have measured the normal fluid density of ^{3}He-B at pressures between 0 and 29.15 bar. By removing Fermi Liquid Effects we examine the effective Yosida function for pressure and temperature dependent strong coupling. The derived gap scaling factor, $\kappa^{-1/2}$, is found to exhibit increased strong coupling effect at high pressures. Further, the temperature dependence exhibited by the strong coupling parameter rules out a constant gap scaling factor.

1. INTRODUCTION

In the course of the last five years, little experimental progress has been made in understanding inconsistencies in the magnitude and pressure dependence of strong coupling corrections to the order parameter of ^{3}He-B. On the one hand, several groups have measured the specific heat of ^{3}He-B (1,2,3) at the transition and in the superfluid phase. The specific heat results show BCS-like behavior at low pressure and an increased amount of strong coupling at higher pressures. However these measurements lack the precision to distinguish between the simple gap scaling theory and the more elaborate weak-coupling plus theory (4) which rules out scaling the gap by a constant factor. In effect, the weak coupling plus model proposes a temperature dependence to the strong coupling coefficients which would reduce their magnitude at low values of T/T_c.However, a determination of the strong coupling correction to the superfluid density by Archie et al (5) indicated that the temperature and pressure dependence of the normal fluid density of ^{3}He-B could be explained in terms of the pressure dependent Landau parameter F_1, together with a single pressure independent gap scaling factor, $\kappa^{-1/2}$. This surprising result contradicts the pressure dependence of the specific heat discontinuity. In this work we have continued to study the superfluid density and by using a temperature scale consistent with the melting curve, (6) find that our results indicate a pressure and temperature dependence to the strong coupling correction factor.

2. EXPERIMENTAL DETAILS

The viscometer was of a standard Andronikashvili type, with a resonant frequency of 400 Hz. Due to our ability to cool the liquid sample to a reduced temperature on the order of 0.25, the zero temperature periods are relatively well characterized and consequently the values of $\rho n/\rho$ are known to $\leq$ 0.5%. The thermometry employed in these experiments uses the melting curve (6) to calibrate a LCMN Thermometer. Data from the torsional oscillator simultaneously allows the determination of the viscosity and the superfluid density through measurements of the dissipation and the period of the oscillator. Although finite size effects dominate the viscosity at low temperatures, it is thought that the effects on the normal fluid density are small. Consequently, relatively precise measurements of the normal fluid density are possible using these devices. Our results for $\rho n/\rho$ vs T/T_c at four pressures are shown in Figure 1.

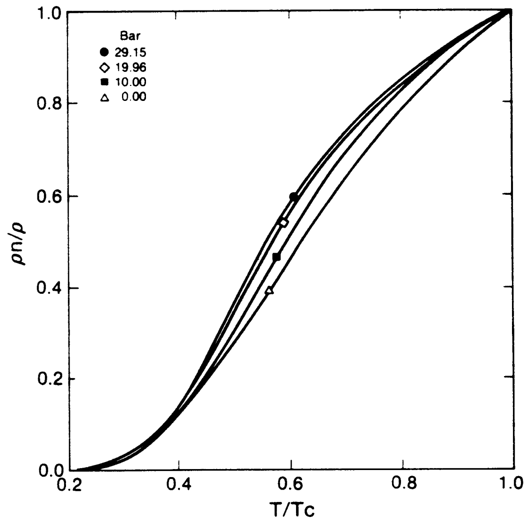

FIGURE 1
The normal fluid fraction is plotted as a function of the reduced temperature for pressures of 0, 10.0, 19.96 and 29.15 bar.

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3. RESULTS

We follow the procedure as used by Archie et al (5) and Saunders et al (7). We present only a portion of our results using values of F_1 from Greywall (8). The effective Yosida function is calculated through the equation

$$Y_{eff} = (\rho_n/\rho)/\left(1 + (F_1/3)(1-\rho_n/\rho)\right).$$

By studying the deviation of Yeff from the BCS Yosida function, the magnitude of the gap can be inferred. We plot the gap enhancement factor $\kappa^{-1/2}$ as a function of T/T_c for four pressures in Figure 2.

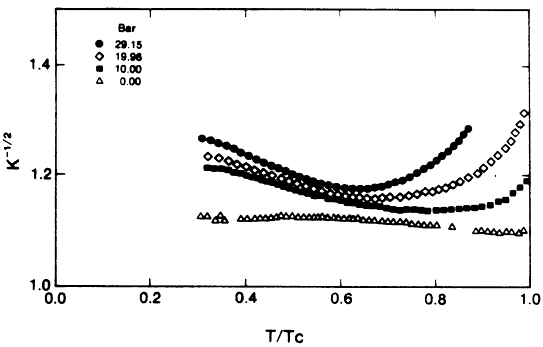

FIGURE 2
The value of the gap enhancement factor $\kappa^{-1/2}$ as determined from measurements of the normal fluid fraction. Note the pressure dependence.

The results for the magnitude of the gap at three pressures are shown in Figure 3.

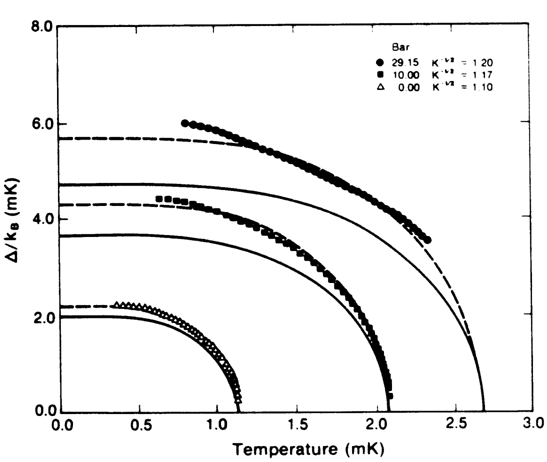

FIGURE 3
We plot the BCS gap (solid lines), and scaled BCS gap (dashed lines) for three different pressures. Experimental values of the gap determined by our analysis are also shown.

The systematic trend with higher pressure to increased strong coupling factors is different to that described by Saunders et al (7). This tendency is replicated regardless of which "group" of F_1 parameters are selected. The scaling parameter is also seen to be temperature dependent, albeit in a complex way. Our values of the gap scaling parameter also differ from those derived from the specific heat jump at T_c. At 0 bar and 29 bar, values for $\kappa^{-1/2}$ determined from (2,3) are 1.2 and 1.0 compared to our results of 1.4 and 1.1.

4. CONCLUSIONS

Preliminary analysis of our normal fluid density results indicate that the gap scaling parameter exhibits a dependence which progressively increases with higher pressures. The magnitude of this gap scaling parameter is found to be temperature dependent and at T_c is not consistent with measurements of the specific heat discontinuity.

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