MASTER

RESEARCH ON THERMOPHYSICAL PROPERTIES OF MATERIALS

Annual Progress Report
for the Period August, 1977 through August, 1978

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We will report progress on our ^3He research for the period August, 1977 to August, 1978 by referring to the attached publication list. Our research on liquids and the liquid engine will be described separately since we have not yet published any of this work.

In [1] we report the discovery of a new type of magnetic relaxation in superfluid ^3He , some of which could be understood in terms of a theory by Leggett and Takagi. In [2] we review for an ultralow temperature symposium some of the frontier concepts and experiments for the superfluid ^3He . Items [3] and [12] detail important new methods and techniques in nuclear cooling apparatus which show how temperatures down to 0.4 mK can be consistently achieved and how temperatures of order 1 to 2 mK can be stabilized to high precision or maintained for long periods of time. Items [4] and [5] summarize the principal results of the thesis of R. E. Sager. In [4] we show new measurements of high accuracy of the static magnetization of $^3\text{He-B}$ which confirm the previous observations here and at Argonne of the discrepancy between the spin and total magnetization changes in the superfluid. In [5] we give the full details of the experiments on magnetic relaxation reported in [1] and include a full experimental characterization of the strange relaxation phenomena in the superfluid. Items [6] through [11] report on a wide variety of discoveries and measurements which we made using essentially a single experimental arrangement using nuclear cooling on which we were more or less constantly making measurements from April of 1977 through April of 1978! In this apparatus we had crossed zero sound propagation systems which we could use to study the orientation of the $\hat{\mathbf{l}}$ field. In [6] we describe follow-on experiments on the persistent orbital motions in $^3\text{He-A}$. We showed that the motions were related to heat flow and that they probably did not reflect motions of the supposed surface trapped objects (like the "boojum"). In [7] we showed that the

orientation of the $\hat{\ell}$ field depends on the sign of an applied magnetic field, just as if superfluid ^3He were ferromagnetic. The effect could only qualitatively be observed, but corresponded to a ferromagnetic moment of reasonable magnitude, according to a theory of Leggett. In [8] we report the discovery of some as yet unexplained oscillations with respect to $\sqrt{1 - T/T_c}$ of the sound attenuation in $^3\text{He-B}$, the effect being largest near zero pressure. In [9] we describe a null effect of an electric field on the orientation of the $\hat{\ell}$ field in $^3\text{He-A}$. We were able to show that the actual effect could not be more than about 10^{-3} of the effect calculated from simple theory. This result was supported by theoretical calculations of Serene and others. In [10] we report the discovery of an excess zero sound attenuation in the normal liquid above T_c . This result then was quantitatively explained by Serene and others. Finally, in [11] we describe magnetic thermometry with CMN diluted to 5% cerium using lanthanum. Such a thermometer is remarkably accurate and indicated a lowest temperature of 0.4 mK. Using the results of this work we reanalyzed many measurements which had been made on the La Jolla scale.

In addition to the above, R. L. Kleinberg finished his thesis measurements on heat flow between parallel plates in $^3\text{He-A}$. This work is not yet written up, but it shows how superfluid velocities can be measured with a magnetic field, finds limiting superfluid velocities, and may show the development of a helical instability in the $\hat{\ell}$ field when $\vec{H}$ is applied parallel to $\vec{v}_s$.

In the liquid engine area we have made excellent progress in a new field. We have set up the means for handling gases and liquids as well as the means for making both equation-of-state and thermal measurements. We have used this equipment to find equation-of-state information on liquid Freon 11. We have learned a great deal about mechanical design and actually built a Malone engine which is to serve as a unique laboratory for studying liquids under novel

nonuniform conditions. We have operated the engine in a state of partial instrumentation and obtained preliminary information on the indicator diagram and some temperatures. Most importantly we have prepared ourselves for the next step with a fully instrumented system.

In the area of electric effects on heat transfer we have built an optical and heat transfer laboratory and are testing optical cells containing Freon 13 near its critical point. We have discovered some new effects of oscillating electric fields on the heat transfer and are currently following these up.

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