IV. LOW-TEMPERATURE PHYSICS

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A. HELIUM LIQUEFIERS

1. Apparatus

The No. 1 Collins helium cryostat has supplied the liquid helium requirements for the low-temperature program of this Laboratory during the past three months.

The No. 2 Collins helium cryostat is in the process of having the latest type engine assemblies and quieter cross-head installed. The engine assemblies allow for much faster servicing of the cryostats and they are much more durable than the earlier ones. This assembly also makes it possible to duplicate the valve tightness which is so important for efficient operation of the cryostats. The quieter cross-head has much less friction in its moving parts. It lends to a better type of piston rod coupling. The lower noise level will be easier on the nerves of those who have to be in the same room with the cryostats.

2. Transportation of Liquid Helium

Until recently the only knowledge we had on the transportation of liquid helium was that which was within walking distances. The equipment necessary has been described in Progress Reports of July 1949 and January 1950. Utilizing this same equipment and taking a few precautions to minimize losses due to movement of the liquid, liquid helium has been transported over a distance of 180 miles with relatively small losses. Four and one-half liters of liquid helium were transported ninety miles by motor car in two hours and ten minutes with a loss of only four-tenths of a liter of liquid. One liter was transferred and the remainder was transported the return trip of ninety miles and stored for several hours; there were two and eight-tenths liters left for servicing experiments. This incident is cited to illustrate the ease of transportation and the practicability of storing a medium-sized amount of liquid helium.

<div align="right">R. P. Cavileer</div>

B. PRESSURE VARIATION OF SECOND SOUND VELOCITY IN LIQUID HELIUM II

The variation of second sound velocity as a function of temperature and pressure has now been measured to 0.95°K and at pressures up to 25 atm. The rise in velocity at about 1° under the vapor pressure is found to persist at these higher pressures. The apparatus was checked for thermal equilibrium by building a sealed dummy chamber

filled with iron ammonium alum. This chamber had the same dimensions as the actual second sound chamber. The susceptibility of the salt was measured simultaneously with the temperature of the helium bath. Since the susceptibility of the salt varies as $1/T$, a plot of the susceptibility versus the reciprocal of the bath temperature should give a straight line, if equilibrium between exterior and interior is established. Such a straight line was found. The velocity data are shown in Fig. IV-1 and deviate about ± 1 percent from the curves drawn through them.
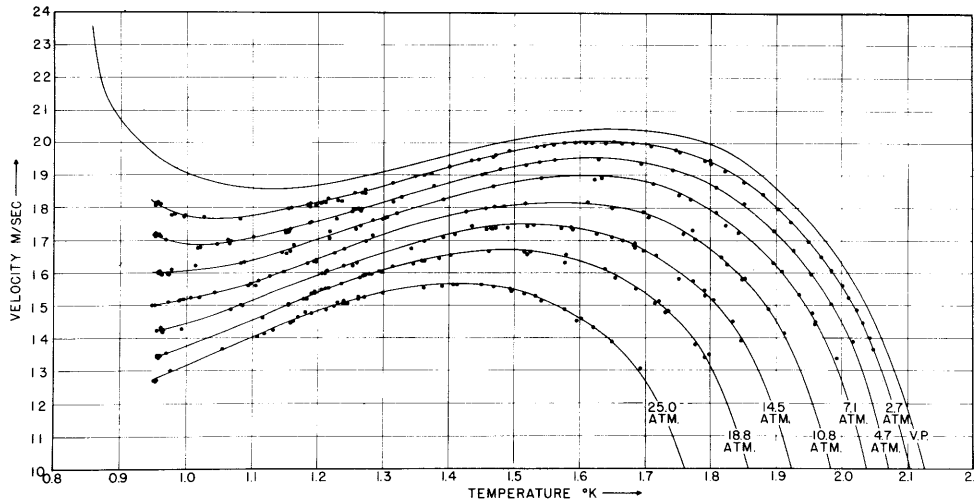

Fig. IV-1 The velocity of second sound as a function of temperature and pressure. Experimental points for the vapor pressure curve are not shown.

Landau has shown that the velocity should approach the value $c_1/\sqrt{3}$ (c_1 is the velocity of first sound) near absolute zero. Since c_1 rises with increasing pressure, one might expect the curves of Fig. IV-1 to cross over at some lower temperature. This prediction of Landau is based on the assumption that the phonons contribute to the "normal" fluid fraction only. Since we were unable to observe this phenomenon, another attack was devised. The rise in velocity itself is presumably due to the phonons. The point where the curve deviated from the extrapolated high temperature curve was determined. It was assumed that this occured when the entropy of the phonons reached some relative proportion of the total entropy, or $s_{phonons}$ = constant $\times$ s. Tisza's empirical expression was used for "s" while s_{phonon} is well known. By differentiating this expression with respect to the pressure, we obtain the pressure variation of the initial deviation.

Our expression $1/T_d \, dT_d/dp = -0.037$ deg/atm-deg is due chiefly to phonon effect. It agrees well with the experimental value of -0.039 deg/atm-deg. This apparently supports Landau's view of the phonon nature in liquid helium II.

A more complete description of this work is being published as an R. L. E. technical report and as a paper in the Physical Review.   R. D. Maurer

C. MAGNETIC DIPOLE INTERACTIONS IN CRYSTALS

The investigation has reached the final stage. Isentropic magnetization curves for potassium chrome alum have been measured for various entropies corresponding to zero magnetic field temperatures as low as 0.017°K. When the family of curves is extrapolated to the absolute zero of temperature by various plots, in all cases the extrapolated curve shows a linear relationship between magnetization and magnetic field until the magnetic field reaches about 90 oersteds where the curve bends abruptly into a horizontal line (saturation). These curves are being measured on cesium titanium alum.

M. B. Prince

D. RESISTANCE MINIMUM MEASUREMENTS

Further measurements have been made of the resistivity of magnesium. The resistivity of samples containing a few crystals made of chemically pure magnesium showed a definite rise in resistivity as the temperature was lowered below 4.2°K. The measurements were extended above the liquid helium temperature range by the use of a helium thermometer and by packing activated charcoal around the sample to reduce the warm-up rate. A definite minimum in the resistivity of one sample was found at about 15°K. A plot of the resistivity versus temperature for this sample is shown in Fig. IV-2.
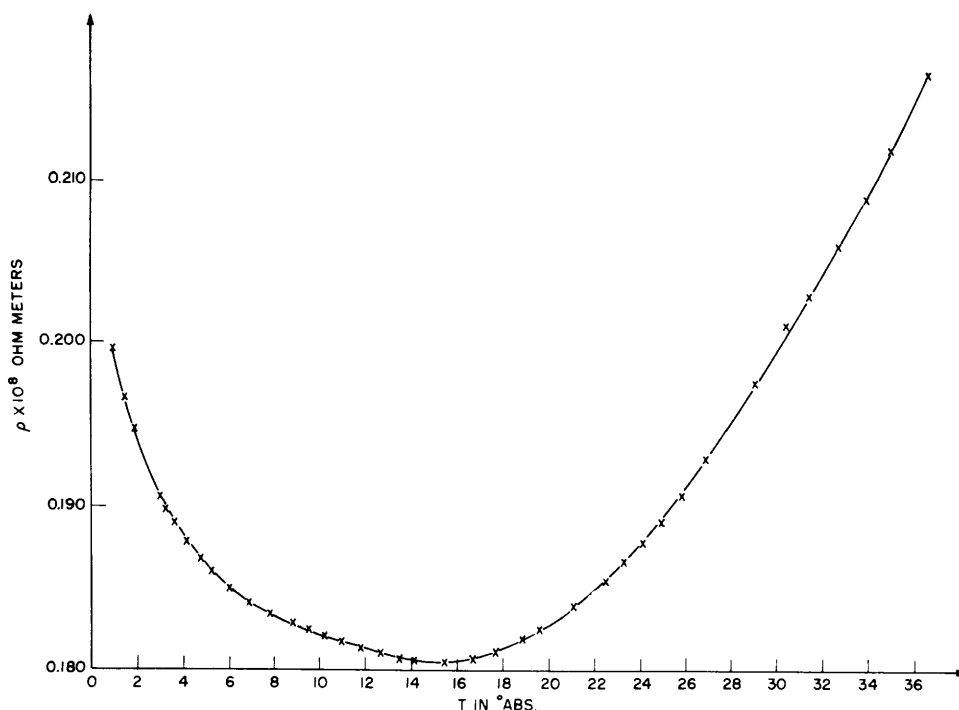

Fig. IV-2 A plot of resistivity vs temperature for a cylindrical sample of magnesium.

Measurements on various samples seem to indicate that the resistance minimum is influenced strongly by impurities, and the role of the impurity content is under investigation. A furnace is being constructed for the preparation of crystalline samples; various metals are to be examined for resistance minimum. Some measurements were made on beryllium, which has a band structure similar to magnesium, but the results were negative.   H. E. Rorschach, Jr.

E. THERMOMECHANICAL EFFECT IN LIQUID HELIUM II

Measurements of the effect at temperatures below 1.9°K were not possible with the fritted tube closed at the top. The fritted tube is always slightly warmer than the helium bath due to radiation leaks and also to the temperature gradient in the gas above the bath; thus the liquid level inside the tube rose to the top and stayed there. The top of the fritted tube was therefore pierced with a small hole so that a pressure gradient could exist between the gas above the liquid in the tube and that above the bath, and thus a temperature gradient across the frit allowed. At the same time pumping could be applied to the fritted tube without the heat leak attendant to bringing it through the dewar cap. The measurements of the effect then were made down to 1.59°K, the ΔT being measured to $\pm 4 \times 10^{-4}$°K with the carbon thermometers. Attention was turned to setting up a diffusion pump to take the measurements below 1°. The equipment has now been set up and only minor difficulties prevent further operation.

                                        D. H. Rogers

F. TEMPERATURE AND PRESSURE DEPENDENCE OF THE VISCOSITY OF LIQUID HELIUM

The investigation is proceeding as described in the Quarterly Progress Report, October 15, 1950, page 26. Construction of the magnetized disk, suspension frame, pressure chamber and the associated coils and electronic equipment (for measurement and temperature control) has been completed.

Preliminary measurements of damping were made with the disk suspended in air at atmospheric pressure, and the theory relating this damping to the viscosity of the medium was developed. The viscosity values thus measured were found to exceed the known value by two orders of magnitude.

All possible causes of this excessive damping are now being examined. Among these, the following appear to merit detailed investigation:

    1. Magnetic feedback between the recording microammeter (which duplicates the motion of the disk) and the disk itself. This effect was found to be quite considerable and steps have been taken to eliminate it.

    2. Losses due to current induced by the disk in surrounding metal parts. In the absence of the brass pressure chamber such losses are negligible since the suspension

frame itself is constructed almost exclusively of plastic. It was found, however, that short-circuiting the inner set of Helmholtz coils (rectangular coils with planes parallel to the axis of the disk) produced considerable damping. This suggests that the brass pressure chamber (which was absent during the preliminary measurements) might introduce enough damping, even at a frequency of 4 cps, to mask entirely any effects due to the viscosity of the medium.

If this is the case, two remedies suggest themselves: magnetization of the disk might be decreased, with a corresponding increase in the amplification of the induced signal. Alternatively, the brass chamber might be lined with lead which would become superconducting during the measurements at liquid helium temperatures.

3. Viscosity of the phosphor bronze suspension wire. Even if this damping were noticeable at room temperatures, it would almost certainly become insignificant at liquid helium temperatures.

4. Friction due to improper mounting of the suspension wires. The 2-mil diameter wires are soldered into steel capillaries. It is possible that the wires are not rigidly attached to the capillaries so that motion of the wire inside the capillaries and consequent friction is not prevented.

The technique employed seems promising despite the above difficulties.

H. H. Kolm

G. SPECIFIC HEAT OF LIQUID HELIUM

Preparations are being made to measure the specific heat of liquid helium in the temperature range from 0.9°K to 1.5°K.

Temperatures in this range will be obtained by means of a diffusion pump.

Temperature measurements will be made with a carbon resistance thermometer, and it is hoped that an accuracy of $\pm 1 \times 10^{-4}$K° can be attained. This high degree of accuracy involves measuring voltages of the order of a microvolt. Suitable equipment has been developed for this purpose, and further research is being carried out in an attempt to increase the sensitivity.

G. C. Hunt