

IV. LOW TEMPERATURE PHYSICS

Prof. M. A. Herlin
B. Bernstein
R. P. Cavileer
C. E. Chase, Jr.

E. E. Huber, Jr.
L. D. Jennings, Jr.
H. H. Kolm

J. S. Mathis
Capt. E. G. Sharkoff
W. M. Whitney
J. W. Wright

A. DETERMINATION OF THE THERMODYNAMIC TEMPERATURE SCALE BY A MAGNETIC METHOD

Design and construction of a liquid-air-cooled solenoid and its associated current control have been completed. This installation gives continuously variable fields of 0 to 2000 gauss over a space approximately 3 inches in diameter and 6 inches long, at 2 volts maximum. Boiling of the liquid air is quite moderate at the maximum power input of 300 watts.

Recently we have been attempting to design a modified helium dewar for use in small electromagnet gaps. This dewar (see Fig. IV-1) utilizes a polished copper radiation shield in contact with a liquid air bath at one end to replace the usual outer dewar containing liquid air. It is apparent that if the radiation shield can be kept at liquid air temperatures, it will be at least as effective as the conventional two-dewar system in reducing radiation of heat inward to the helium. For comparable inner dewar size the conventional system would require a magnet gap of approximately 3 inches.

J. W. Wright

B. ELECTRICAL AND THERMAL CONDUCTIVITY OF MAGNESIUM

A series of magnesium samples (extruded rods approximately 0.5 inch in diameter) was obtained from the Dow Chemical Company. The manganese content of these samples varied from 0.01 percent to 1.1 percent, as shown by spectroscopic analyses furnished by the Dow Chemical Company. The condition of the manganese impurity in these specimens was not accurately known, although this condition did not affect the qualitative results obtained.

The thermal conductivity of each of the five samples containing manganese impurity was measured as a function of temperature, and the results are shown in Fig. IV-2. The logarithm of the thermal conductivity of each of the samples at a given temperature is plotted against the logarithm of the impurity content in Fig. IV-3. For a given temperature these points lie on a straight line having a slope of approximately $-3/4$. An exception is the sample containing 1.1 percent manganese, which has a thermal conductivity corresponding to an impurity content of about 0.5 percent manganese. This behavior can be explained by the fact that a large percentage of the manganese content in the sample was not in solid solution as a result of the heat treatment in extrusion.

The Lorentz number (the product of the thermal conductivity and the electrical resistivity divided by the temperature) is of theoretical interest in relating thermal

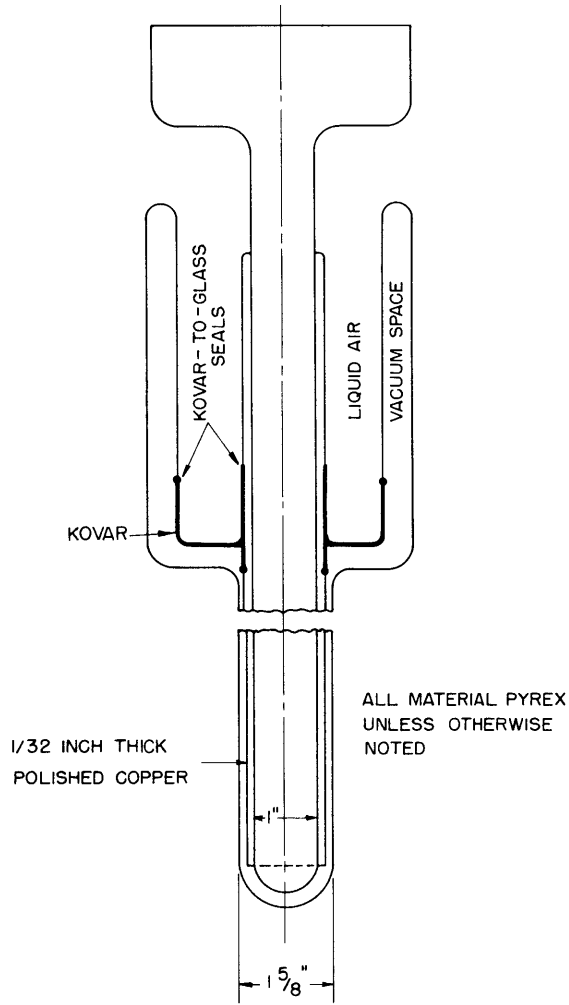


Fig. IV-1
Helium dewar for use in
small magnet gaps.

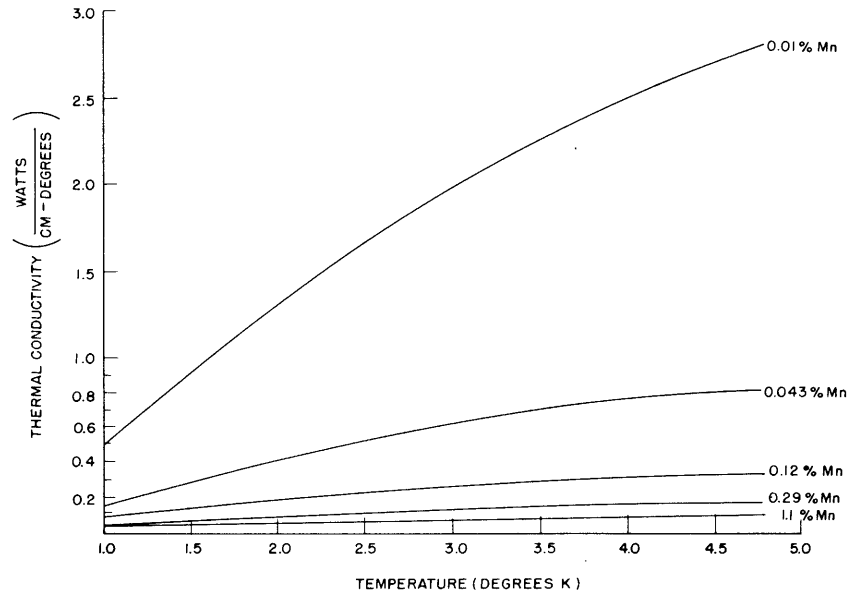


Fig. IV-2
Thermal conductivity of magnesium as a function of temperature
with various amounts of manganese content.

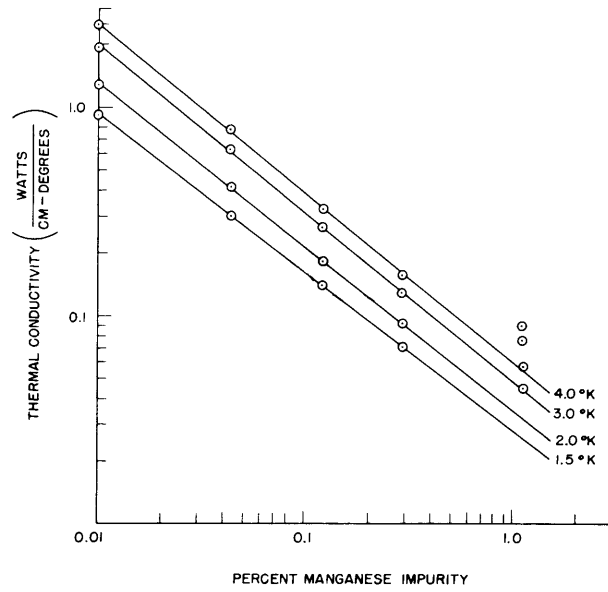


Fig. IV-3
Thermal conductivity as a function of manganese content.

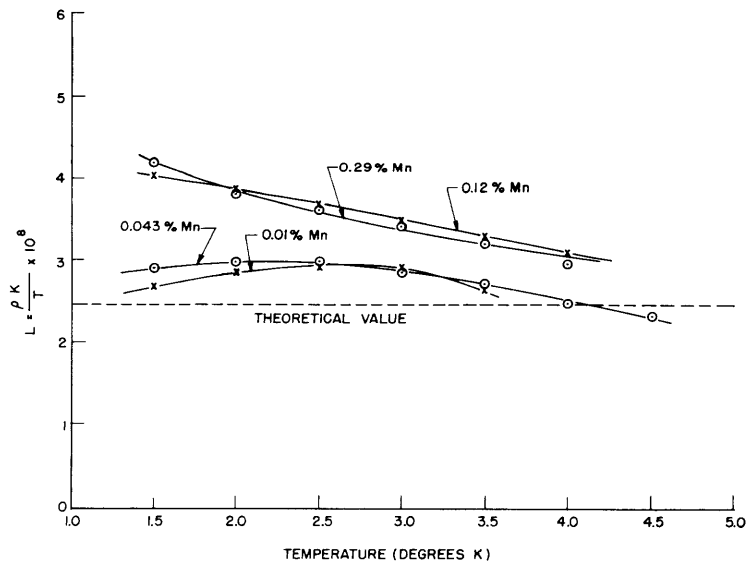


Fig. IV-4
Lorentz number as a function of temperature.

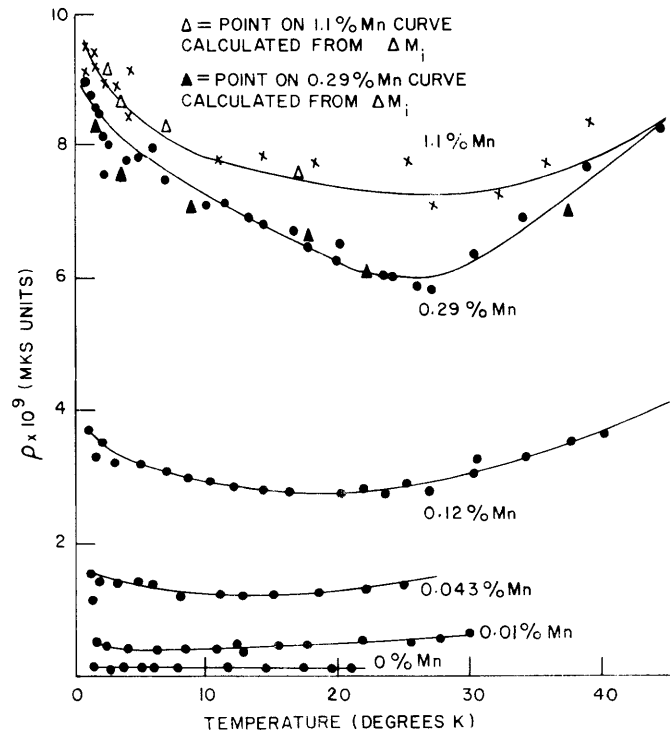


Fig. IV-5

Electrical resistivity as a function of temperature for various amounts of manganese content.

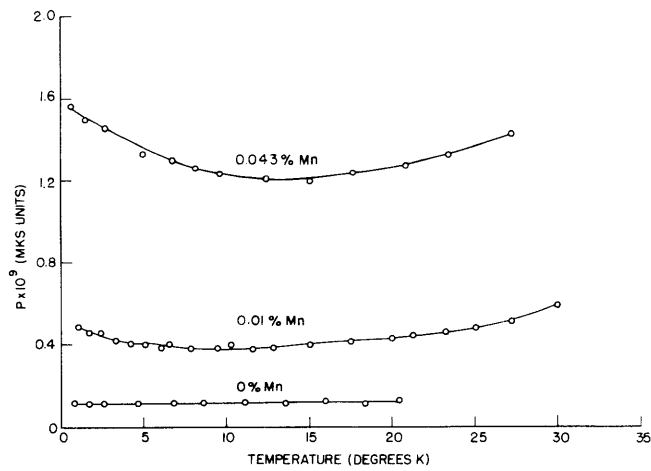


Fig. IV-6

Resistivity of 0 percent, 0.01 percent, and 0.043 percent manganese content plotted to a larger scale than in Fig. IV-5.

(IV. LOW TEMPERATURE PHYSICS)

conductivity measurements to electrical resistivity measurements, since this number should be a constant in an ideal metal where a mean-free-path can be defined. Curves of this number as a function of temperature are shown in Fig. IV-4. Electrical resistivity data, shown in Figs. IV-5 and IV-6, were taken by J. S. Mathis, who used the method of H. E. Rorschach, Jr.

The plot of the Lorentz number vs temperature shows that the mechanism producing the electrical resistance minimum effect in magnesium affects the thermal conductivity in the same qualitative way as it affects the electrical resistance, since the values found are all quite near the value predicted by theory. However, the variation of Lorentz number with temperature shows a negative second derivative for low impurity content, which increases to a positive value for the highest impurity content examined. Thus, the mechanism does not have the same quantitative effect on the thermal conductivity as it has on the electrical resistivity.

E. G. Sharkoff

C. SECOND-SOUND PULSE AMPLITUDES IN LIQUID HELIUM II

A satisfactory phosphor-bronze, wire-wound receiver for the thermal pulses has been constructed after several trials. The resistance vs temperature curve of this receiver has been determined with good reproducibility between 1.35°K and 1.80°K. The amplitudes of second-sound pulses were then measured around 1.4°K as a function of the power-per-unit-area heat input to the helium. The transmitter used was the original type of graphite coating on Bakelite. The data obtained are given in Table I.

The first set of data involved an experimental uncertainty of approximately 10 percent due in large measure to a low-frequency pickup that made the oscilloscope amplitude comparisons difficult. The second set was taken after elimination of this pickup, and its experimental uncertainty should be 5 percent or less. The observed pulse amplitudes are compared with values to be expected from the formula $\Delta T = W/\rho c c_2$, where W is the heat input per unit area, ρ is the density, c is the specific heat, and c_2 is the second-sound velocity. Actually, the theoretical values listed are calculated as twice the formula value on the assumption that 100 percent reflection takes place at the Bakelite receiver backing.

A representative second-sound pulse waveform observed at 1.43°K is drawn to scale in Fig. IV-7. A 200- μ sec input voltage pulse of the kind used to generate the second sound, divided down and put through the receiver amplifying and display system, shows 25 to 30 μ sec rise and fall times. In Fig. IV-8 the initial received pulse and its first two echoes are roughly drawn. These echoes have undergone one and two reflections from the graphite on the Bakelite transmitter, respectively, in addition to their reflections from the receiver backing.

(IV. LOW TEMPERATURE PHYSICS)

Table I

Temperature (degrees K)	Pulse Amplitudes (degrees)	
	Observed (± 10 percent)	Theoretical
1.38	0.76×10^{-3}	0.80×10^{-3}
1.42	1.4	1.34
1.40	0.73	0.80
1.40	0.96	0.97
1.39	1.2	1.21
1.38	3.1	2.9
	Observed (± 5 percent)	Theoretical
1.42	1.26×10^{-3}	1.22×10^{-3}
1.40	1.14	1.20
1.46	1.05	1.05
1.45	1.23	1.24
1.45	1.14	1.14

Future plans include lowering the temperature range of these measurements from about 1.2°K down to the lowest degree attainable, using a Distillation Products MB-200 oil diffusion pump to achieve greater pumping speeds on the helium.

B. Bernstein

D. THE VISCOSITY OF LIQUID HELIUM

The frictionless magnetic bearing and its associated equipment have been transferred from the temporary bench stand used for preliminary tests to a substantial steel frame which is to support the cryostat. By weighting the frame and mounting it on absorbent felt pads, the level of mechanical noise has been reduced to a tolerable level during night hours.

After some experimentation with a variety of materials, a new design for the rotor was achieved. It was found that the compressive strength of pyrex is adequate to withstand the forces arising when iron collars of suitable design shrink onto the tapered extremities of a pyrex centerpiece when the entire assembly is cooled to liquid-air temperature. A rotor which is concentric to better than 0.0001 inch has been constructed and has been found to be sufficiently well balanced (dynamically) for use at the speeds in question. Inasmuch as cooling involves a certain hazard of breakage, this rotor will not be cooled until some measurements have been made at room temperature to verify the suitability of the present design.

H. H. Kolm

(IV. LOW TEMPERATURE PHYSICS)

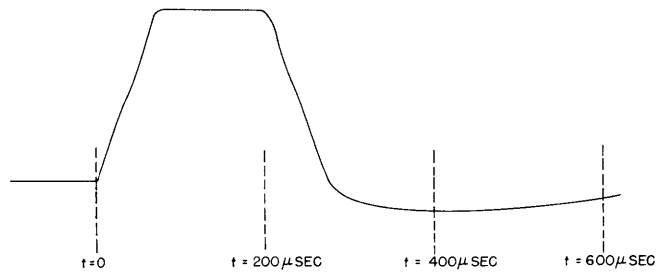


Fig. IV-7
Second-sound pulse at 1.43°K .

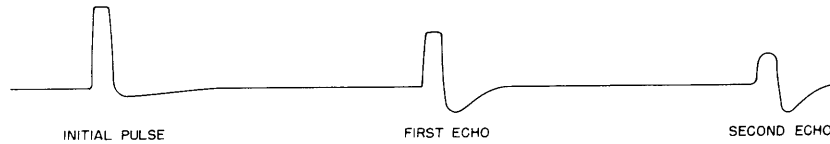


Fig. IV-8
Initial received pulse and echoes.

E. VELOCITY AND ATTENUATION OF FIRST SOUND IN LIQUID HELIUM
BELOW 1°K

The construction of apparatus for the measurement of the velocity and absorption of first sound in liquid helium at temperatures below 1°K is being continued.

A comparison has been made between experimental results obtained earlier at frequencies of 2, 6, and 12 Mc/sec and a theory due to Khalatnikov (1,2). This theory assumes that the anomalously high attenuation of sound in helium II is caused by relaxation processes connected with the establishment of equilibrium in the numbers of elementary excitations present in the liquid (phonons and rotons). Khalatnikov shows that two of these processes, phonon-phonon and phonon-roton interactions, are dominant, and that the third possible process, interactions between rotons, is of negligible importance. According to Khalatnikov, the two relaxation times should be of equal order of magnitude.

Numerical calculations based on the best available values of the many parameters in the theory show that qualitative agreement can be obtained, but that the quantitative agreement is poor. The best fit to the experimental curves results from the assumption that the relaxation time for phonon-phonon interactions is very short compared with that

(IV. LOW TEMPERATURE PHYSICS)

for phonon-roton interactions. At the frequencies used in the experiments and at temperatures above 1°K, this indicates that the attenuation is chiefly due to disturbances in the equilibrium of the numbers of rotons, and that the phonon gas is in equilibrium at all times. At lower temperatures, however, this picture will be changed. The Khalatnikov theory shows that both relaxation times are becoming rapidly longer as the temperature is lowered, and it is probable that the phonon-phonon relaxation time will become important at temperatures of the order of 0.8°K. (The experimental data at 0.85°K indicate that even there the frequency dependence of the attenuation is not consistent with a single relaxation time.) If this is the case, the curve of attenuation against temperature may be expected to exhibit two maxima corresponding to the two relaxation processes, one of which has been observed in the neighborhood of 0.9°K and is identified with phonon-roton interactions, and the other, due to phonon-phonon interactions, at some lower temperature.

C. E. Chase, Jr.

References

1. I. M. Khalatnikov: J. Exptl. Theor. Phys. (U.S.S.R.) 20, 243, 1950
2. I. M. Khalatnikov: J. Exptl. Theor. Phys. (U.S.S.R.) 23, 8, 1952