IV. LOW-TEMPERATURE PHYSICS

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A. HELIUM LIQUEFIERS

1. Apparatus and Operation

The No. 2 Collins helium cryostat is now fully equipped with the latest design of engine assemblies, a quieter crosshead, magnehelic indicator, and several over-pressure safety devices.

This cryostat has been thoroughly tested and its performance is very satisfactory. Using precooling on both the radiation shield and in the subpot the cooling-down time is one hour and fifteen minutes, from room temperature to liquefying. The added fifteen minutes is due to the increased mass in the new engine assemblies. The rate of liquefaction averages a strong four liters per hour.

The quieter type of crosshead has more advantages than merely a lower noise level. It gives better balance to the machine since the two engines operate 180° out of phase instead of in unison. The connection of valve rods is much easier and quicker since the valve openings are preset in the crosshead. The delicate adjustment of piston rod setting is eliminated. There is also a greater flexibility of operation since the timing adjustment of the intake valves for each engine is independent of the other.

The magnehelic differential pressure gauge which gives the pressure differential across the low-pressure channel of the Joule-Thompson heat exchanger allows for more uniform operation of the cryostat to maximum production, since a more delicate setting of the Joule-Thompson valve can be maintained.

The good rate of liquefaction is attributable to tighter valves, made possible by the new engine assemblies and the magnehelic indicator.

Following are figures on cryostat operation and liquid helium services for the calendar year 1950.

Total runs	92	
Running time	543	hours
Helium liquefied	1,282	liters
Liquid nitrogen used	6,260	liters
Individual experiments serviced	345	

2. Storing Liquid Helium

Liquid helium service can be available on two successive days with one run of the cryostat by storing the liquid in an intermediate supply vessel. But the radiation losses of the vessel must be reduced; this is accomplished by keeping the vessel in a bath of liquid nitrogen. The bath is maintained by an automatic filling and level-controlling device.   R. P. Cavileer

B.   MAGNETIC DIPOLE INTERACTIONS IN CRYSTALS

Many attempts have been made to obtain isentropic magnetization curves for cesium titanium alum by using a mechanical balance method. They have been unsuccessful because the heat leak from the bath temperature to the magnetically cooled salt has been too great to get reliable results. We are now in the process of changing the experimental technique to one in which we will measure the differential susceptibility of the salt vs. magnetic field. Integration of this curve will give the magnetization curve. This setup will enable the helium heat transfer gas to be pumped out of the sample holder before the large magnetic field is removed, thereby limiting the heat leak to that through a glass rod two inches long.

It might be said that the previous experimental method is still a good one for properly chosen salts. The only restriction on the salt is that it be a stable one with respect to its water of crystallization; that is, it must not lose this water. It is just this that makes cesium titanium alum unfit for the original experimental technique. The water lost by the salt wetted the glass capsule and caused a large quantity of the salt to stick to the glass, thereby creating the large heat leak.   M. B. Prince

C.   RESISTANCE MINIMUM MEASUREMENTS

The furnace for the construction of metallic crystals has been completed and tested by making aluminum crystals (see Quarterly Progress Report, January 15, 1951). The crystal-growing technique required refining; the crystals grown have not been of good quality.

Further measurements on resistance minima have been made. A sample of very pure aluminum was investigated, and some indication of a possible resistance minimum was observed immediately above the superconducting transition temperature. The sensitivity of the apparatus was restricted by the size of the aluminum sample. A larger crystalline sample made in the furnace gave no indication of a minimum. However, this sample was very impure, as indicated by a very broad transition range.

The resistivity of gold has been measured in the liquid helium temperature range. The resistivity was found to rise steadily as the temperature was lowered from 4.2° K

to 0.9°K, in conformity with the results obtained by de Haas and van den Berg at Leiden.

Further measurements have been made on the resistivity of magnesium. A sample obtained from Dow Chemical Company with an impurity content very nearly the same as previous samples that showed a resistivity minimum at 15°K, exhibited a minimum at approximately 9°K. Some very pure samples of magnesium are being procured from the A.E.C. to investigate further the role of impurities in resistance minimum effects.

H. E. Rorschach, Jr.

D. THERMOMECHANICAL EFFECT IN LIQUID HELIUM II

The experimental apparatus now includes a Distillation Products MB200 diffusion pump (100 liters/sec capacity) with one, two, or three Kinney pumps as forepumps. When the pumping system was used at 1°K it was found to pump erratically, due to a "bumping" in the oil diffusion pump, and this resulted in large temperature fluctuations. An electronic temperature control system has been designed and constructed. The original sensing device was a carbon resistor made by removing the ceramic casing from an old-fashioned 70-ohm, one-watt carbon resistor. The electronic system controlled the current through a small constantan heater immersed in the helium bath. Since there appeared to be a time delay in the response which could be accounted for only by a delay in the change of the carbon resistor, this resistor was replaced by a piece of carbon strip resistor. However the strip resistor appears to be no more effective, and better regulation is desired. Measurements of the thermomechanical effect have been made at the upper end of the range of temperatures reached by the present pumping system, 1.13°K to 1.16°K; but the pumping fluctuations became larger as the temperature was reduced below 1.13°K.

D. H. Rogers

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

Our attempt to measure the viscosity of liquid helium at pressures above the vapor pressure was described in the Quarterly Progress Reports of October 15, 1950 and January 15, 1951.

The first measurements in liquid helium revealed that damping of the disk increased considerably when the apparatus was cooled to liquid helium temperatures, and that this excessive damping was not due to the viscosity of the medium. Since the resistance of the inner set of coils (measuring coils) decreases from 150 ohms at room temperature to about 3 ohms at liquid helium temperature, this damping could be explained by assuming that one or several turns of the inner coils had become short-circuited. To verify this assumption, the damping was measured as a function of coil resistance during the warm-up period following the experiment. It was found that the damping decreased abruptly

to almost its value at room temperature (i.e. the logarithmic decrement decreased from $25 \cdot 10^{-3}$ to about $5 \cdot 10^{-3}$). The resistance increased from 3 ohms to about 5 ohms, whereas there was no substantial change in damping while the resistance increased from about 5 to 150 ohms.

It thus appears that the excessive damping is not simply related to the resistance of the inner coils; nevertheless, the damping failed to appear in a subsequent experiment in which the inner coils had been removed entirely and motion of the disk was observed by means of the signal induced in the outer deflecting coils (a technique which is not suitable when a metal pressure chamber surrounds the disk). The excessive damping has not been explained satisfactorily.

New inner coils will be made with silk-insulated wire in place of the No. 40 "Formex" wire now used, at the expense of sensitivity.

In the event that it proves impossible to reduce the induction damping sufficiently to render the viscous damping measurable, it will be necessary to resort to the less satis-factory method of observing the disk by capacitive means.

H. H. Kolm

F. SPECIFIC HEAT OF LIQUID HELIUM

Measurement of the specific heat of liquid helium was found to be impossible with the equipment previously described, due to the large heat leak into the inner chamber. The inner chamber could be completely isolated thermally from the helium bath by a vacuum space, but a large heat leak occurred from room temperature via the wires to the resistance thermometer and heating element. It was determined to overcome this difficulty by passing the wires through the helium bath before leading them out of the Dewar flask.

This decision necessitated a complete redesign and reconstruction of the apparatus, which has been accomplished.

G. C. Hunt

G. MEASUREMENT OF SECOND-SOUND PULSE HEIGHTS IN LIQUID HELIUM II

Equipment has been built and measurements made on the amplitudes of second-sound pulses in liquid helium II for given power input at various temperatures. The results will be checked against theoretical predictions.

The second-sound tube is a bakelite rectangular cylinder closed by carbon transducer strips at each end; one carbon converts an electrical voltage pulse input into the second-sound temperature pulse, and the other carbon converts the received second-sound into an output voltage pulse by means of its resistance change. The output pulse is fed into a high-gain video amplifier followed by an integrating component which makes the pulse amplitude measurement possible in spite of the high degree of submersion of the received signal in noise.

B. Bernstein

H. WAVE IMPEDANCE OF LIQUID HELIUM II IN THE NONEQUILIBRIUM THEORY

A distinction has been made between nonequilibrium and local equilibrium theories of liquid helium II by Band and Meyer. A modified form of their thermodynamic results in the nonequilibrium case has led us to the following expression for the wave impedance (ratio of temperature fluctuation to heat input of a pulse) in the nonequilibrium limit:

$$\frac{\Delta T}{W} = \frac{x}{x' c_2 \rho u}$$

where x is the fraction of normal fluid, x' is its temperature derivative, ρ is the density, and u the "heat content". The second-sound velocity c_2 is given by

$$c_2^2 = s \frac{1 - x}{x}$$

where s is the entropy. This second-sound velocity expression agrees with the equilibrium expression of Tisza and Landau if s and x are proportional, but differs at low temperatures where they are not proportional.

The fraction x has been computed numerically on the basis of the nonequilibrium expression for c_2, and these data used to compute the wave impedance. Curves of these two quantities as a function of temperature are shown in Figs. IV-1 and IV-2.
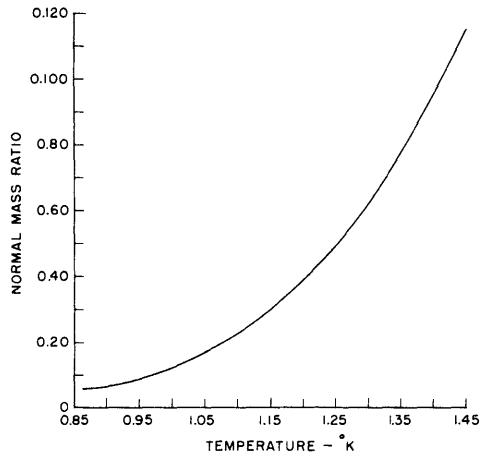
J. S. Dewitt

Fig. IV-1

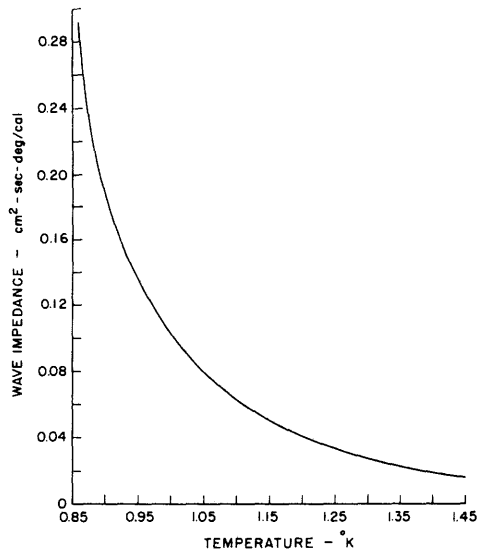Mass ratio of normal fluid as a function of temperature.

Fig. IV-2

Wave impedance as a function of temperature.