

#### IV. LOW-TEMPERATURE PHYSICS

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##### A. HELIUM LIQUEFIERS

The No. 1 Collins helium cryostat has been tested with the scheme of replacing the large or top engine by leading the inlet gas, as it would ordinarily come to the top engine, through an eighteen-foot copper coil which is immersed in liquid nitrogen.



Fig. IV-1 Liquid delivery tube valve.

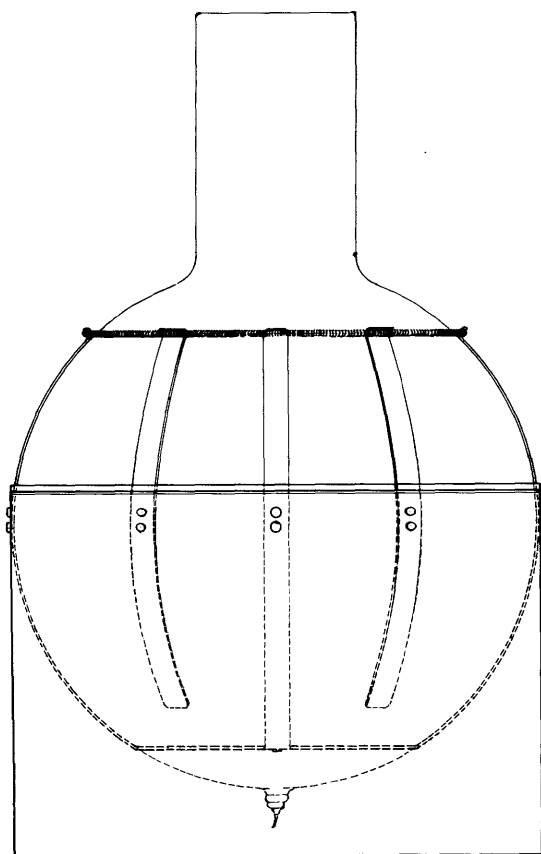


Fig. IV-2 Dewar stand.

The cooling down time is not shortened; it is about the same as that of using the small engine and precooling on the radiation shield, two and three quarters hours. The rate of liquefaction is an average of four liters per hour. Figure IV-1 in the Quarterly Progress Report of January 15, 1950 illustrates this scheme.

The valve arrangement illustrated in Fig. IV-1 has been adapted to the liquid delivery tube of the cryostats and found to be very satisfactory. The chief advantage is that the flow of liquid may be stopped before removing the collecting dewar.

The commercial five-liter dewar is usually sealed into its stand by a tar bond. Such a bond is unsatisfactory when putting the dewar in a liquid nitrogen bath. The tar becomes brittle and due to the contraction of the metal stand being greater than that of the glass at low temperatures, the tar cracks away. The stand shown in

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Fig. IV-2 has proved very satisfactory. The fingers are of phosphor bronze and the holding spring is such as is used for belts in motion picture projectors.

R. P. Cavileer

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

The second sound apparatus for obtaining the values given in the Quarterly Progress Report, July 15, 1950 has been found in need of modification. These values were not reproducible and the difficulty was traced to blocking of the capillaries that transmit the pressure. A second exit capillary has been connected to the chamber and terminated in a check gauge to establish the existence of pressure equilibrium. The pressure variation of the velocity between 0 and 25 atm and as low as  $0.9^\circ$  has now been satisfactorily measured with a deviation of about 0.5 percent. These measurements have not yet been checked for temperature equilibrium although estimates indicate that this will not introduce a very large correction. Subject to this modification, our values show that the rise in velocity is depressed to lower temperature by an increase of pressure. Within this temperature range the curves at constant pressure diverge somewhat instead of converging as they must in order to conform with Landau's theory.

R. D. Maurer

#### C. MAGNETIC DIPOLE INTERACTIONS IN CRYSTALS

The investigation of critical transfer gas pressures for different salts in different shaped capsules has been completed. The only additional datum that should be added to the table in the Progress Report of July 15, 1950 is that for granular cesium titanium alum in capsule size 2, where the transfer gas pressure should be 80 mm of helium at  $300^\circ\text{K}$ .

Samples have been cooled by adiabatic demagnetization in the large Bitter magnet with currents of 5000 amp giving a magnetic field of 50,000 gauss. The lowest obtainable temperatures are found to depend upon the speed at which the current is reduced to zero. For one sample, KCr alum in capsule size 2, we have been able to reach  $0.07^\circ\text{K}$  with the magnetic field turned off in eight seconds, and to reach  $0.05^\circ\text{K}$  when the magnetic field is turned off in two seconds. The heat leak into the capsule is such that the salt can be kept within  $0.05^\circ\text{K}$  to  $0.10^\circ\text{K}$  for a period of ten minutes.

Morton Prince

#### D. MEASUREMENTS OF RESISTANCE MINIMA BY INDUCTION

The resistivity of magnesium has been measured. An extruded sample of commercial stock showed a possible rise in resistivity as the temperature was lowered in the liquid helium range, but the amount of change was not greater than the experimental uncertainty. A sample of more pure metal and much larger crystal size showed a rise at low temperature which was far greater than experimental error, although the residual resistivity was larger than that of the extruded sample. A sample which was intended to

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be a single crystal, but actually contained two crystal boundaries, showed essentially the same behavior as the second sample.

The translation of the real and imaginary parts of the mutual inductance of the measuring coil with the sample at the center into electrical conductivity has been greatly improved. Good approximations have been found to make the calculation of finite length cylindrical samples in a finite coil reasonably simple. H. E. Rorschach, Jr.

#### E. THERMOMECHANICAL EFFECT IN LIQUID HELIUM II

The effort to measure the temperature difference between the helium bath and the fluid inside the frit system, using the vapor pressures above the two systems, has been abandoned. Although the differential McLeod gauge could measure pressure differences of the order expected, the pressure gradient along the lines leading to it (due to pumping on parts of the system) could not be diminished enough to make the measurements possible. Since phosphor bronze resistance thermometers have not yet been developed at this Laboratory, attention was turned to carbon resistance thermometers. After some search suitable ones have been found and installed. Measurements of the effect have been made at 2.15°, 2.04° and 2.01°K. The thermometers are very sensitive so that it is necessary to install heat-absorbing glass along both unsilvered slits of the dewar. Attempts to measure the effect at 1.86°K resulted in "blow overs", i. e. the fluid in the inner tube could not be cooled rapidly enough by pumping to offset the heat conducted from above and that from the warmer walls contacted by the fluid as its height increases. For work at this temperature and lower, the fritted tube will be closed off, not be allowed to come to the dewar cap, and will be supported from the bottom. The butterfly valves which were constructed had leaks which were too large for them to be usable; however, with the fritted tube closed at the top, manual control of the bath pressure is possible. D. H. Rogers

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

Keesom and MacWood (1) have measured the viscosity of liquid helium as a function of temperature in the range between about 1°K and 4°K and at atmospheric pressure. The viscosity was found to decrease from about 30 micropoise at 4° to about 20 micropoise at the  $\lambda$ -point, at which a discontinuity followed by a sharp decrease was observed. Viscosity then appears to vanish asymptotically with decreasing temperature. This viscosity-temperature curve is distinguished by its low values (the viscosity of most gases at standard conditions is of the order of 130 micropoise), and by its positive slope (characteristic of "kinetic" or gas-type viscosity rather than the "dynamic" viscosity exhibited by all other liquids).

An investigation of the behavior of second sound velocity now nearing completion in

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this Laboratory (2) indicates that pressures as low as 25 atm exert a considerable effect on second sound propagation, an effect not accounted for by any of the current theories. It is of theoretical interest to determine experimentally the effect of comparable pressures on the behavior of the viscosity of liquid helium, i. e. to obtain viscosity-temperature curves at various values of pressure above the vapor pressure line.

The method of measuring the damping effect on a thin disk oscillating in liquid helium (employed by Keesom and MacWood) appears to be the most satisfactory technique for the problem at hand. It is not practical, however, to couple such a disk mechanically to the outside of the pressure chamber surrounding it. The following apparatus is therefore being constructed:

A disk about 1.2 cm in diameter and 1 mm thick, made of Alnico 5 and magnetized along a diameter, is suspended inside a pressure chamber by means of two phosphor-bronze wires attached to the extremities of a thin, rigid shaft passing through the center of the disk and normal to its plane. The disk is thus free to oscillate about its axis against the restoring torque provided by the phosphor-bronze wires, and the period of this free oscillation is approximately one second.

Motion of the disk can be controlled and observed with the aid of three sets of Helmholtz coils. Two of these sets are located outside the Dewar system: one provides a d-c field in the direction of magnetization of the disk by means of which the resonant frequency may be adjusted, while the other provides a component at right angles to the field of the first and thus serves to deflect the disk from its rest position. A third and much smaller set of coils, parallel to the deflecting coils, is located inside the pressure chamber.

The natural frequency of the mechanical suspension (1 sec) represents the minimum suspension to provide adequate strength; most of the restoring torque is thus provided magnetically, a measure which reduces to a minimum the inevitable residual damping due to the suspension. A frequency of 4 cps is being used. After the disk has been excited to oscillation of known amplitude by means of the exciting coils, its motion may be observed by amplifying and recording the signal induced in the inner set of coils. Damping is expected to be such that the oscillations will have a time constant of about 20 to 30 minutes; and it is therefore necessary to provide a device for maintaining the temperature of the helium bath surrounding the pressure chamber (or the pressure above the helium bath) constant during this period of time. Construction of the apparatus and associated electronic instruments is nearing completion.

H. H. Kolm

#### References

1. W. H. Keesom, G. E. MacWood: *Physica* 5, 737 (1938).
2. Cf. sections on the pressure and temperature dependence of second sound velocity in the Quarterly Progress Report, July 15, 1950 and in this report.