

IV. LOW-TEMPERATURE PHYSICS

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A. HELIUM LIQUEFIERS

The performance of the A. D. Little number two cryostat has been so pleasing that it has been called upon to carry the whole load of helium production for the past several months.

The number one cryostat is undergoing modification so that it will be able to duplicate the performance of the number two cryostat as to rate of production and convenience of assembly.

It has been found that it is possible to operate the cryostat with the upper or large engine disconnected. The refrigeration from the liquid nitrogen pre-cooling of the radiation shield is substituted for this engine. The cooling time is a bit longer and the rate of production is a little less when the lower or small engine is used alone. This points out that it is possible to maintain operation if the large engine develops trouble; pre-cooling and the small engine will maintain operation until it is convenient to take time-out to adjust or repair the large engine.

The following figures on cryostat operation are for the three-month period ending June 1, 1949:

number of runs.....	35
experiments serviced.....	84
number of liquid helium transfers.....	146

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1. Intermediate Supply of Liquid Helium

It had become apparent that research problems would arise utilizing liquid helium in which it would be awkward to transfer the liquid helium directly from the cryostat to the experiment. Therefore a mobile supply would be desirable and most useful.

The accompanying sketch illustrates the essentials of the scheme. The Dewar is a commercial five-liter American Thermos which was stripped and then resilvered with a window so that the level of the liquid could be observed.

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In transferring into the intermediate Dewar it is necessary to take a few precautions: first, the Dewar must be pre-cooled with liquid nitrogen;

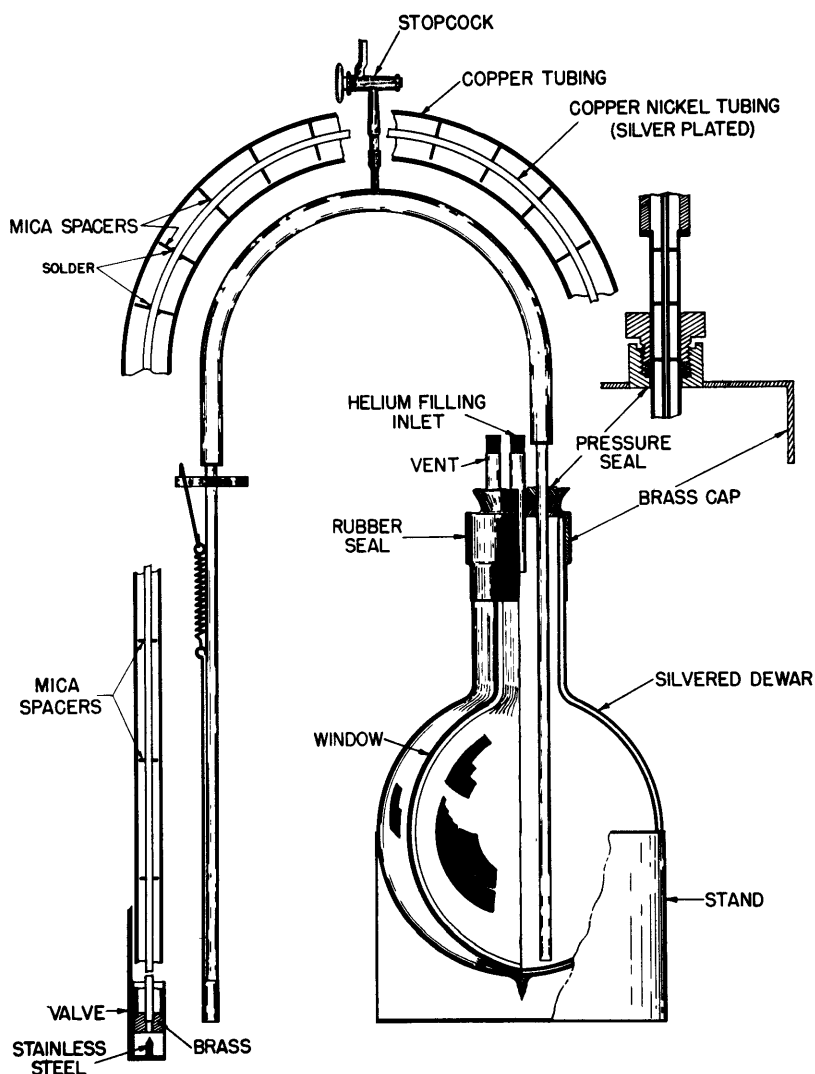


Fig. IV-1 Liquid helium transfer tube.

second, with the transfer tube already installed in the cap it is flushed with helium gas. After pouring the liquid nitrogen out of the Dewar, a trickle of gas is kept flowing through the tube in reverse as the cap is placed on the Dewar. This gas is kept flowing through the transfer tube until the delivery tube of the cryostat has been inserted into the Dewar, thereby assuring an over-pressure of helium vapor in the Dewar. The gas line may then be removed and the cap valve placed on the transfer tube without running the chance of air getting into the transfer tube.

When the liquid helium is transferred into the experimental Dewar, solid rubber stoppers are placed in the "Helium Filling Inlet" and "Vent"

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tubes in the cover on the Dewar. This allows for a pressure build-up in the Dewar so that when the cap valve is removed from the transfer tube there will be an overpressure on the liquid helium to force it over.

The transfer tube can be made less fragile by sealing the vacuum off in the pig-tail below the glass sections as shown. It is also satisfactory to seal the tube with air in it for the liquid helium temperature will freeze out the air and create a good-enough vacuum for transfer purposes.

For the purpose of reducing the loss of liquid by evaporation from the intermediate supply, the intermediate Dewar is kept in a bath of liquid nitrogen.

This transfer tube and Dewar as a mobile supply of liquid helium have been used sufficiently to prove satisfactory in every respect.

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B. MICROWAVE SURFACE IMPEDANCE OF SUPERCONDUCTORS

Measurements on tin, mercury and lead have been completed and a Technical Report prepared. Despite the fact that no appreciable deviations of the measured surface resistance from the calculated value were found in normal state (except for lead where it was impossible to obtain an uncontaminated surface), the observed residual resistance in the superconducting state at the lowest temperatures used ($\sim 2^\circ\text{K}$) appears to be of the same order of magnitude as with previous investigations and does not seem to be extrapolable to zero at zero temperature. The change of reactance in the superconducting state was measured, and a method was indicated for obtaining the limiting value of the penetration depth λ_0 by means of the theory of P. M. Marcus (R.L.E. Technical Report in preparation). The values of λ_0 obtained for Sn, Hg and Pb were 4.7, 7.3 and 5.4×10^{-6} cm respectively. The temperature dependence of the penetration depth λ was derived from the resistive and reactive parts of the surface impedance of all the three metals. From measurements in the normal state, the effective numbers of free electrons in tin and mercury were estimated to be 0.30 and 0.13 per atom (mean values), respectively.

Dr. I. Simon

C. MAGNETIC COOLING

Work on this project was held in abeyance because of the initiation of the study of second sound velocity.

D. X-RAY STUDY OF SUPERCONDUCTORS

A Debye-Scherrer camera has been constructed for use at liquid-helium

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temperatures and has been tested at liquid-air temperatures. Satisfactory diffraction patterns of lead have been obtained at 88°K and, in particular, the alpha doublets of the back reflection lines have been clearly resolved. This resolution should be sufficient to detect the very small line splittings that are being searched for in the superconducting state.

Supplementary experiments have shown that the lead sample in the camera can be maintained in the superconducting state sufficiently long for adequate exposures, and diffraction patterns of the superconducting material will be made very shortly. The x-ray facilities have been very kindly provided by Professor B. E. Warren.

E. SECOND SOUND VELOCITY

Experiments have been completed to measure the velocity of second sound in liquid helium between 0.86°K and 1.5°K. A pulse method was used because of its possibilities for attaining such measurements at very low temperatures. The apparatus employed by Pellam in this laboratory (1) was essentially reconstructed for the purpose.

The low temperature was obtained by means of a high-capacity pumping system without the use of diaphragms or capillaries. A Distillation Products type MB-100 diffusion pump was connected with two Cenco Hypervac 25 forepumps. This system was directly connected by a large diameter pipe to the two concentric double-walled Dewars. The outer Dewar contained liquid air. The inner one was specially constructed so that its walls joined about 10 cm from the top. A liquid air level was maintained above this point in order to reduce the conduction of heat down the inner wall to the liquid helium.

Below 0.92°K, it was found necessary to correct the temperature values as determined from vapor-pressure readings. This was done by comparing the susceptibility of iron ammonium alum, which varies as $1/T$, with the temperature as found from the vapor pressure. The final data are shown in Figure IV-2 and definitely illustrate the rise in velocity first detected by Peshkov (2). The strength of the second sound pulses was found to increase markedly with decreasing temperature and there was qualitative indication that the thermo-mechanical effect remained strong down to 0.86°K.

These results lend partial corroboration to the theory of Landau (3) regarding the role of the phonons in the superfluid fraction. However, recent experiments with He^3 do not support Landau's contention with respect to rotons but substantiate the London-Tisza view of a Bose-Einstein condensation (4). A paper on this work has been submitted to the Physical

Review and is being issued as a technical report.

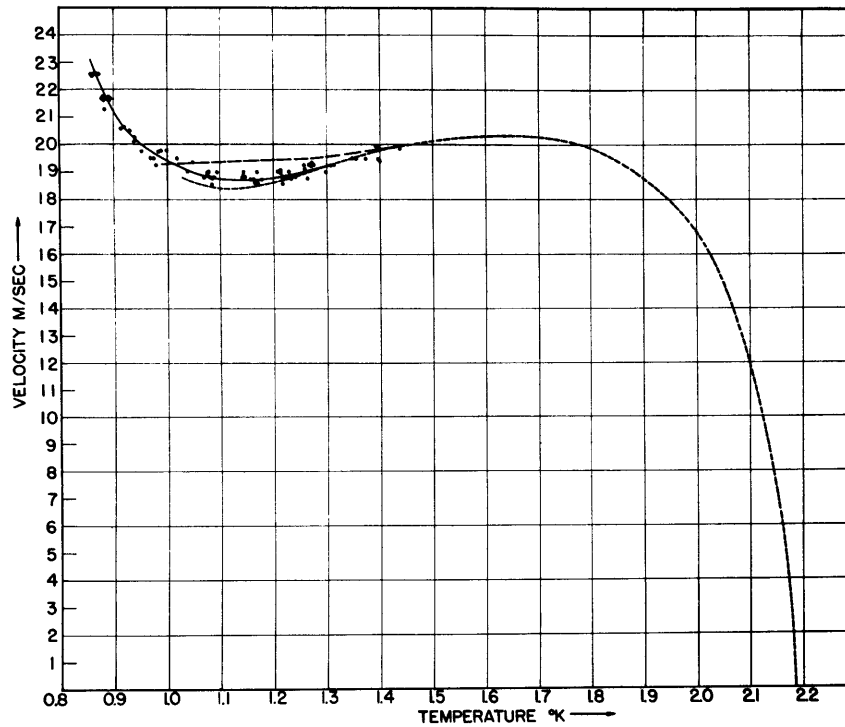


Fig. IV-2 Second sound velocity as a function of temperature.

— — — curve drawn from Pellam's data.
- - - - curve from Peshkov.
— — — curve fitted to authors' data.

References

- (1) J. R. Pellam, Phys. Rev. 75, 1183 (1949).
- (2) V. Peshkov, J.E.T.P. USSR 18, 951 (1948).
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