

#### IV. LOW-TEMPERATURE PHYSICS

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##### A. HELIUM LIQUEFIERS

For the past quarterly period the following is a summary of cryostat operation and services

Number of runs	20
Running time	107.8 hours
Experiments serviced	81

Figures on cryostat operation and services for a full calendar year give an interesting comparison with the previous year.

	1948	1949
Number of runs	119	71
Satisfactory runs	107	69
Efficiency	90 percent	97 percent
Experiments serviced	122	195

In comparing the number of runs and the experiments serviced it will be noted that much has been learned in coordinating the program.

The scheme of utilizing a modified 5-liter dewar and vacuum-jacketed transfer tube as an intermediate supply of liquid helium has been used more than 100 times with perfect satisfaction.

R. P. Cavileer, J. W. Toomey, Jr.

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

The apparatus used by J. R. Pellam (1) in his measurements of the velocity of pulsed second sound was modified by Maurer and Herlin (2) to permit increased pumping speeds and attain lower temperatures. Provisions have now been made for varying the pressure within the second sound chamber over the range between the vapor pressure and the solidification lines. Measurements have been made along the vapor line down to 0.86°K. Peshkov (3) measured second sound velocity to 1.03°K, although his measurements at varying pressure were extended only to 1.3°K.

Preparations are in progress for measuring second sound velocity at various

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pressures below 1°K. The capillaries through which the conductors pass into the second sound chamber have been effectively sealed for pressures up to 500 lbs/in<sup>2</sup>. A capillary has been installed in the tube through which helium is condensed into the second sound chamber in order to minimize heat transfer from superfluid film creep up the tube. A thermocouple pressure gauge was installed to provide a continuous check on the stability of temperature, which could not be obtained by use of the McLeod gauge alone. The pump manifold was modified so as to permit the use of several forepumps in parallel, and at present the electronic equipment is being improved in signal-to-noise ratio and the speed with which data may be taken.

E. H. Jacobsen, H. H. Kolm, R. D. Maurer

#### References

- (1) J. R. Pellam: Technical Report No. 89, Research Laboratory of Electronics, M.I.T. (1948); Phys. Rev. 75, 1183 (1949).
- (2) R. D. Maurer, M. A. Herlin: Technical Report No. 124, Research Laboratory of Electronics, M.I.T. (1949).
- (3) V. Peshkov, J. Phys. USSR 10, 389 (1946); J.E.T.P. USSR 18, 951 (1948).

#### C. INVESTIGATION OF DIPOLE INTERACTION IN CRYSTALS

This investigation depends upon the fundamental techniques of adiabatic demagnetization which are being developed to a point where consistently successful runs can be made as far as reaching low temperatures is concerned. The lowest temperatures reached in this Laboratory to date have been in the range of 0.024 - 0.04°K; but these temperatures could not be attained consistently. A survey program has been initiated to determine how to prepare samples of different salts and crystal sizes in order to get consistently low temperatures. The proper amount of heat exchange gas seems to be the critical factor.

M. B. Prince

#### D. COOLING LIQUID HELIUM BY ADIABATIC DEMAGNETIZATION

In the past quarter a good deal of time has been spent on apparatus and instrumentation problems. Since we hope to choose a salt which has a specific heat anomaly in the working temperature range, and which therefore does not follow Curie's law in this range, the susceptibility of the salt cannot be used as a good measure of the temperature. The simplest solution to the temperature measurement problem seems to be a resistance thermometer whose resistance is a simple, easily extrapolated function of temperature. After experimentation, the conclusion has been reached that small carbon (not composition) resistors with a room-temperature resistance of about 50 ohms

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are the best for our purposes. These seem to follow a straight line in a  $\log R$  vs.  $1/T$  plot, i. e. are simple semiconductors in the desired range; to have a temperature coefficient large enough to give accurate results, yet not so large that the resistance becomes difficult to measure at low temperatures; and to be quite reproducible during any one run. We estimate that accuracy of the order of 0.5 percent in the temperature will be attained fairly easily.

In experiments with resistance thermometers, it was noted that above the  $\lambda$ -point it took an hour or two for the bottom of the helium bath to come into equilibrium with the surface (the surface temperature was measured by the vapor pressure, and the bottom temperature by the resistance thermometer) when the temperature was raised, but not when it was lowered. This consequence of the extremely low heat conductivity of liquid helium I when the temperature gradient is in such a direction as to preclude convection should be taken into account in the design of experiments.

Demagnetization experiments will be tried in a short time with a carbon resistance thermometer imbedded in partially dehydrated chromic sulfate. An attempt will be made to use the superconducting-tantalum heat switch of Daunt and Heer.

V. Mayper

An attempt is being made to perfect an apparatus in which it will be possible to maintain a mixture of liquid helium and a paramagnetic salt at a lowered temperature for an extended period of time. One of the eventual purposes is to enable measurements of the specific heat of helium below  $1^\circ\text{K}$ .

A preliminary model has been made in which a mixture of a paramagnetic salt (ferric ammonium sulfate) and liquid helium was lowered from an initial temperature of about  $1.5^\circ$  to a final temperature of about  $0.9^\circ$ . The warm-up rate of the mixture was small enough for some experiments, a complete return to equilibrium taking place in 15 to 30 sec. We hope to decrease this rate.

The apparatus used consists of a vacuum-jacketed glass container which contains the paramagnetic salt. The helium is allowed to enter the container through a fritted funnel (a bacteria filter) which is placed in one end of the container. The initial lowering of temperature is accomplished by adiabatic demagnetization.

G. C. Hunt

#### E. MEASUREMENT OF MAGNETIC SUSCEPTIBILITY

The magnetic susceptibility of paramagnetic salts has been measured in this Laboratory by means of a mutual inductance bridge. The component upon which the ultimate sensitivity seems to depend is the detector. The 35-cps oscillator signal must be measured with a sensitivity of the order of a few microvolts, and at the same time reject power line pickup, power supply ripple voltage, and especially oscillator harmonics, at different frequencies. A General Radio wave analyzer was used originally, and performed

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very satisfactorily, but this apparatus has many features which are not necessary for this purpose, and the cost is correspondingly high. We have therefore developed a selective amplifier circuit, consisting of two stages of a regenerative filter circuit, in addition to a low-pass stage. This selective amplifier circuit can be built in the laboratory easily, and several of these along with the bridge components are being constructed for use in the various experiments requiring the measurement of magnetic susceptibility. Experiments are being started to investigate the use of this apparatus for measuring electrical resistances of metals at low temperature by eddy current induction.

M. A. Herlin

#### F. MAGNETIC COOLING

Continuous refrigeration below  $1^{\circ}\text{K}$  by repeated demagnetization calls for thermal or heat switches. Those under investigation are a mechanical switch in which two metal plates are squeezed together, and a solid-liquid helium switch operated over the pressure range, 24 atm-26 atm. Results with the helium switch are not yet ready to be reported.

Two silver plates  $3/4$  in. in diameter, ground and polished to approximately optical flatness, have shown a satisfactory heat conductance in vacuum near  $1^{\circ}$  when squeezed by a force of 40 lbs. With one plate kept at  $1.2^{\circ}$ , and the other comprising the end of a capsule containing 33 grams of iron ammonium alum charged with helium, the capsule went from  $8^{\circ}$  to  $1.3^{\circ}$  in about 1 min upon squeezing with 40 lbs. The first part of the cooling was slow, presumably because of the low conductivity inside the capsule above the  $\lambda$ -point, while the cooling from  $2^{\circ}$  to  $1.3^{\circ}$  occurred in around 10 sec. Squeezing at 15 lbs., the cooling from  $8^{\circ}$  to  $2^{\circ}$  was some 20 times slower, and it more or less ceased before equality of temperature was reached. It then appears that, with sufficient squeezing pressure, the heat of magnetization at  $1^{\circ}$  can be removed less than 1 min, whereas it had previously been feared this would not be possible by this method.

A three-stage machine using such mechanical switches is now under construction. It is felt that the easiest way to find whether the switches will conduct satisfactorily far below  $1^{\circ}$  is to try them in place.

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S. C. Collins, C. D. Fulton