

IV. LOW-TEMPERATURE PHYSICS

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A. HELIUM LIQUEFIERS

Production of Liquid Helium. The Collins helium cryostats have been given their most rigorous test to date. During the past quarter liquid helium was produced for the work of twelve undergraduate theses in addition to the requirements of the research program of the low temperature group. All of the requirements of the two programs were met on schedule. The following figures summarize the helium production.

Number of runs	27
Running time	173 hours
Liquid helium produced	364 liters
Experiments serviced	116

Reduction of Cool-Down Time. The number of experiments serviced stimulated an effort to reduce the cool-down time. By using the auxiliary liquefying pot as a liquid air precooling line, in addition to the usual radiation shield line, the cool-down time was reduced to one hour. That is, one hour after starting the machine helium begins to liquefy.

Fountain Effect Photography. Figures IV-1 and IV-2 illustrate the thermo-mechanical properties of liquid helium II. These photographs show the fountain more clearly than previously published fountain pictures. For the photography we are indebted to Prof. H. E. Edgerton, and to Mr. B. J. Diver of this Laboratory.

R. P. Cavileer

B. PRESSURE VARIATION OF SECOND SOUND VELOCITY IN HELIUM II

Equipment capable of measuring the velocity of second sound in liquid helium II at temperatures down to 0.9°K and at pressures between the solidification line and the vapor pressure line has been completed.

Measurements made thus far indicate that the second sound velocity rise observed at low temperatures either disappears, or occurs at temperatures below the range of the present equipment when the pressure is raised. Curves at 1 atmosphere and at

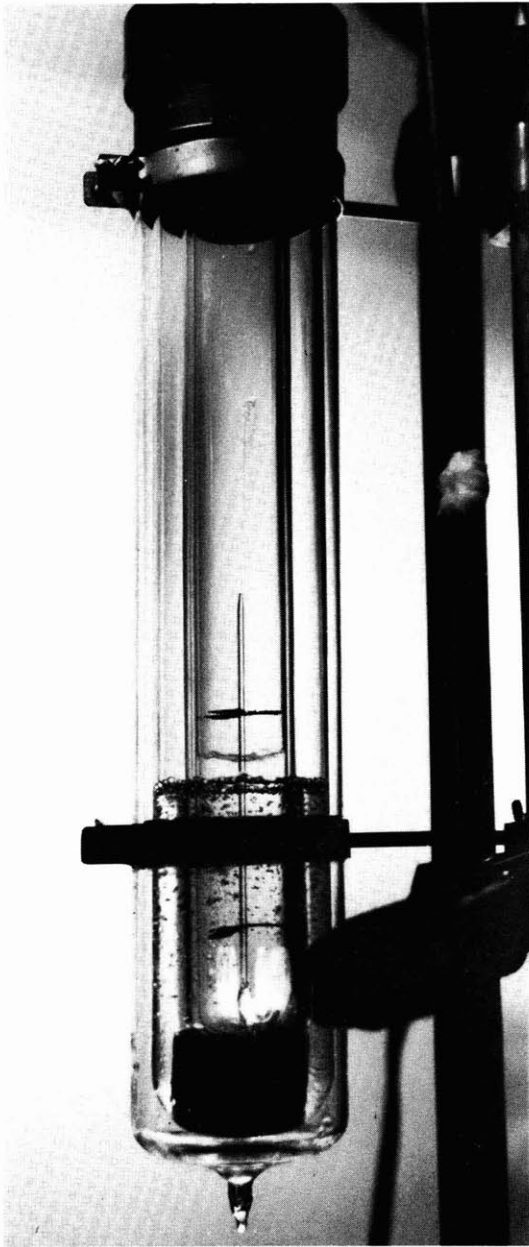


Fig. IV-1 Helium fountain.

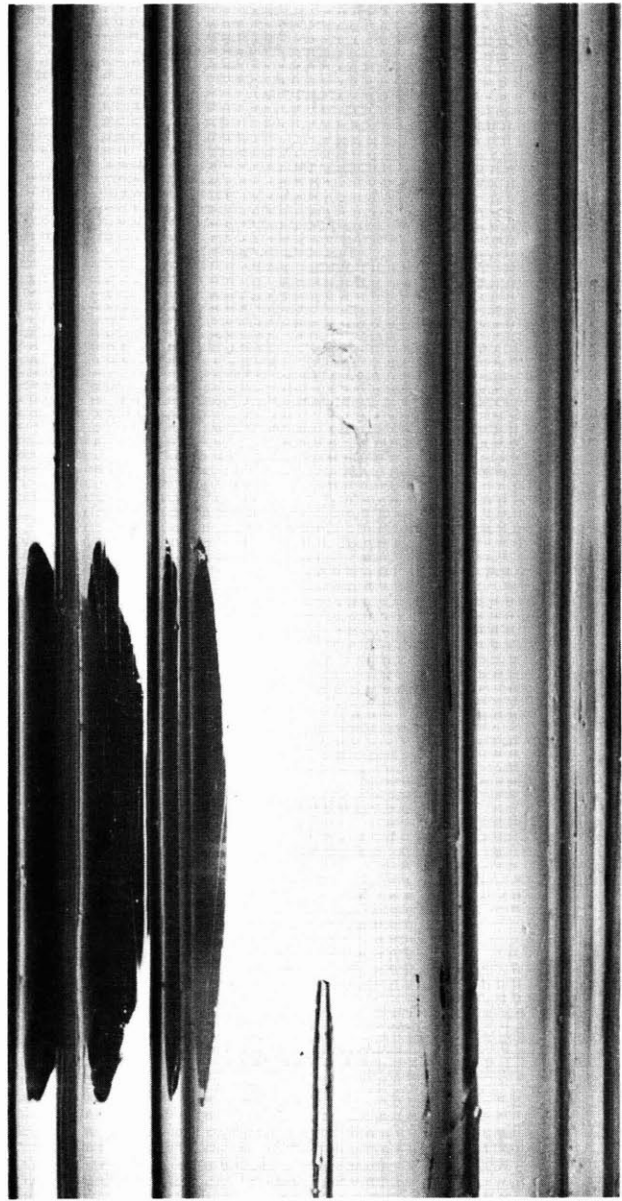


Fig. IV-2 High-speed photograph of helium fountain (photographed by Prof. Harold E. Edgerton).

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25 atmospheres have been taken, and appear in tabular form below. More extensive data are being taken .

1 atmosphere		25 atmospheres	
temperature (°K)	velocity (m/sec)	temperature (°K)	velocity (m/sec)
1.28	18.94	1.025	17.81
1.27	19.05	1.025	17.73
1.27	18.99	0.98	17.52
1.13	18.39	0.97	17.42
1.06	18.58	0.948	17.34
0.99	18.66	0.925	16.91
0.98	18.67	0.91	16.88
0.98	18.89	0.90	16.96
0.97	18.89	0.90	16.84
0.97	18.86		
0.94	19.21	estimated systematic error	
0.93	19.17	temperature:	$\pm 0.01^\circ\text{K}$
0.92	19.38	pulse travel	
0.90	19.64	time:	$\pm 5 \mu\text{sec}$

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

C. MAGNETIC DIPOLE INTERACTION IN CRYSTALS

The survey program that was announced in the Quarterly Progress Report of April 15, 1950 is in its final stage. The results that have been obtained are as follows:

Salt	Crystal Size	Capsule Size	Critical Pressure of Transfer Gas
FeNH ₄ Alum	Large - 2.0 gm	1	19 mm of He at 300°K
FeNH ₄ Alum	Medium - 0.25 gm	1	22 mm of He at 300°K
FeNH ₄ Alum	Small - 0.02 gm	1	25 mm of He at 300°K
K Cr Alum	Granular	1	20 mm of He at 300°K
K Cr Alum	Granular	2	60 mm of He at 300°K

Capsule size 1 is a cylinder 20 mm in diameter, 100 mm in length, filled one-third with salt. Capsule size 2 is a 20-mm sphere filled with salt, with a 40-mm stem of 6 mm diameter.

An aging effect was noticed in the large crystals of FeNH₄ Alum. On consecutive runs, the surface of the crystals became more powdery and more helium gas had to be

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introduced to provide sufficient transfer properties.

In determining the pressures above, adiabatic demagnetization runs were made with a field of 5500 gauss, and temperatures of the order of 0.1°K to 0.2°K were reached with a warm-up rate such that the initial temperature was again reached after 30 to 60 seconds.

M. B. Prince

D. COOLING LIQUID HELIUM BY ADIABATIC DEMAGNETIZATION

Effort has been directed chiefly to the development of a suitable demagnetization apparatus. Considerable time was spent in tentative experiments with superconducting-tantalum and solid-helium heat switches, but the conclusion was finally reached that the standard method of conducting heat from salt to bath with a transfer gas, then pumping out the transfer gas, was the most reliable method of isolating the capsule containing magnetized salt. Apparatus for this method has been constructed and tested, and awaits its first run.

V. Mayper, Jr.

Investigation of various sources of heat leak into apparatus in which liquid helium is cooled by adiabatic demagnetization has not disclosed the principal source of such heat. Radiation, conduction across the vacuum jacket, and conduction down the pumping line have been eliminated tentatively until the source of greatest heat leak is isolated and eliminated. The Rollin film is being investigated.

G. C. Hunt

E. MEASUREMENT OF RESISTANCE MINIMA BY INDUCTION

The mutual induction bridge and coils which have been developed for measuring magnetic susceptibility are being adapted to the measurement of electrical resistance through the complex mutual inductance of a coil containing the specimen. This method has been applied to a sample of magnesium which has been reported to have a resistance minimum in the neighborhood of 4°K. A rising resistance which has been detected as the temperature falls indicates the existence of such a minimum. The temperature control equipment is being improved, and the frequency of the bridge current is being reduced from 33.3 cps to 3.7 cps in order to get greater penetration of the induced currents into the sample.

This technique for measuring electrical resistance has the advantage of absence of connecting leads and a more convenient form of the sample, especially if single crystals are to be measured.

H. E. Rorschach, Jr.

F. INTERMEDIATE STATE OF TIN

Measurements were made of the mutual inductance and associated loss resistance at 33 1/3 cps of a coil containing a cylindrical tin core; the core was immersed in liquid helium and its temperature thus varied from 4.22°A to 1.65°A. The quantities measured

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remained fairly constant down to 3.74°A . At this point they both began decreasing rapidly, very nearly linearly for the mutual inductance and monotonically but not quite so linearly for the resistance, until 3.50°A was reached. Further lowering of the temperature showed an abrupt levelling of both curves; each quantity maintained down to 1.65°A the value it had attained at 3.50°A . The curves indicate the coincidence between the resistive and diamagnetic properties of the intermediate superconducting state.

B. Bernstein

G. THERMOMECHANICAL EFFECT AT LOW TEMPERATURE

In order to make measurements of this effect it is necessary to control the temperature of the main bath of liquid helium automatically. There are too many other adjustments and readings to be made to allow manual control, unless several operators are available. Simon (1) designed an on-off valve for the pumping line controlled by a manostat-thyratron system, which was made to control the vapor pressure above the bath and hence the temperature of the bath. This device was designed for operation at the λ -point and above. The sensitivity of the control was later improved by the use of a bellows of metal foil in place of the mercury manostat. The bellows soon developed rather serious leaks to helium gas, so were replaced by a U-tube manostat, with conducting oil as the fluid rather than mercury. The oil used is diethylene glycol with a few drops of sulphuric acid (concentrated) added. The oil manostat is even more sensitive than the bellows, and the manometers on the system do not follow the very small pressure fluctuations necessary to operate it. The on-off valve designed by Simon does not have the capacity necessary for pressures to give temperatures lower than 1.8°K , so a solenoid-operated butterfly valve has been constructed but not yet tested.

The pressure difference between the inner system and the bath was first measured with oil manometers, but the small temperature difference between the liquid helium in the fritted tube and that in the surrounding bath has necessitated the construction of a differential McLeod gauge to read the pressure difference with sufficient accuracy.

Heat must be supplied to the helium within the fritted tube in small amounts. Manipulation was simplified by the use of a light on the outside rather than a heater on the inside inasmuch as it is not necessary to measure the total heat input. Heat leakage between the inside and outside of the fritted tube has been troublesome, and it is hoped that the vacuum jacket now being added to the tube will improve the results.

D. H. Rogers

Reference

- (1) I. Simon: Rev. Sci. Inst. 20, 832-833 (1949).

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H. SENIOR THESES

During the past academic term the low temperature laboratory has supplied facilities for ten senior theses, in addition to supplying liquid helium for two others in paramagnetic absorption. Two of these are reported above, namely, the pressure dependence of second sound velocity by Jacobsen and Kolm, and the cooling of liquid helium by adiabatic demagnetization by Hunt. Other experiments performed by seniors include work on a superconducting heat switch, following Daunt and Heer, by W. E. Krag; attempts at the excitation of second sound by filtration of first sound (R. V. Dyba) and by magnetization of a paramagnetic salt (C. E. Chase, Jr.); measurements of the thermal conductivity of free-machining brass by J. F. Goff; specific heat measurement of iron ammonium alum by H. B. Jenkins and A. Lurio; and construction of a superconducting galvanometer by J. Uretsky.

These projects could not be carried far in the short time allowed for an undergraduate thesis, but they provided an excellent introduction to low temperature laboratory techniques for the men who worked on them, and they added a great deal of practical experience to the fund of techniques available to the laboratory as a whole. Further, a number of high-risk experiments could be tried at relatively little expense, and those which proved fruitful will be carried further. This effort is felt to be in the direction of unifying the research and teaching efforts of the laboratory.

M. A. Herlin