

IV. LOW-TEMPERATURE PHYSICS

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A. HELIUM LIQUEFIERS

During the three-month period (Dec. 1, 1948 - Mar. 1, 1949) both of the Collins Helium Cryostats have fulfilled all requirements of the low-temperature research program.

The cryostat engines and valve mechanism have been completely trouble-free during this period.

It has been learned that if a minute leak should develop at low temperatures in the stainless-steel Dewar vessel (vacuum jacket) of the liquefier, there is a possibility of maintaining adequate vacuum by increasing the pumping speed of the diffusion pump. This is accomplished by increasing the voltage on the heater element which in turn gives a higher operating temperature of the diffusion-pump oil. This expedient can be used when time is an object in meeting deadlines.

The following figures indicate the performance of the cryostats during this three-month period:

number of runs.....	28
experiments serviced.....	69
number of transfers of liquid helium into external dewars.....	101

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B. CLEAR DEWARS

A set of clear (unsilvered) Dewar vessels have been constructed for use in exhibiting liquid helium, and showing some of its peculiar properties, such as the fountain and creep effects. One of the more interesting features observed is the apparent low rate of evaporation of the liquid helium in this setup. The arrangement consists of the inner Dewar, containing liquid helium, surrounded by a jacket of liquid nitrogen contained in an outer Dewar. The inner Dewar contains a millimeter of air between the walls and this is used as a heat-transfer gas for pre-cooling the Dewar to liquid-nitrogen temperature.

It is not necessary to flush the inner Dewar with helium gas to prevent the collecting of ice on its walls, for the helium vapor will flush

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it before the liquid actually starts collecting.

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C. MICROWAVE SURFACE IMPEDANCE OF CONDUCTORS IN THE NORMAL STATE

Measurements on the surface conductivity of copper, silver, tin and lead from 300°K to 5°K at 24000 Mc/sec have been completed. Our final results on these metals will appear soon in a technical report.

D. MICROWAVE SURFACE IMPEDANCE OF SUPERCONDUCTORS

Most of the time in the last quarterly period was devoted to the measurements on tin in the superconducting state at 10,000 Mc/sec. Some of the results are summarized in Figure IV-1. A composite curve describes the normalized surface resistivity R/R_n as a function of temperature, and another curve shows the resonance-frequency shift below transition temperature. It is possible to obtain the penetration depth λ as a function of

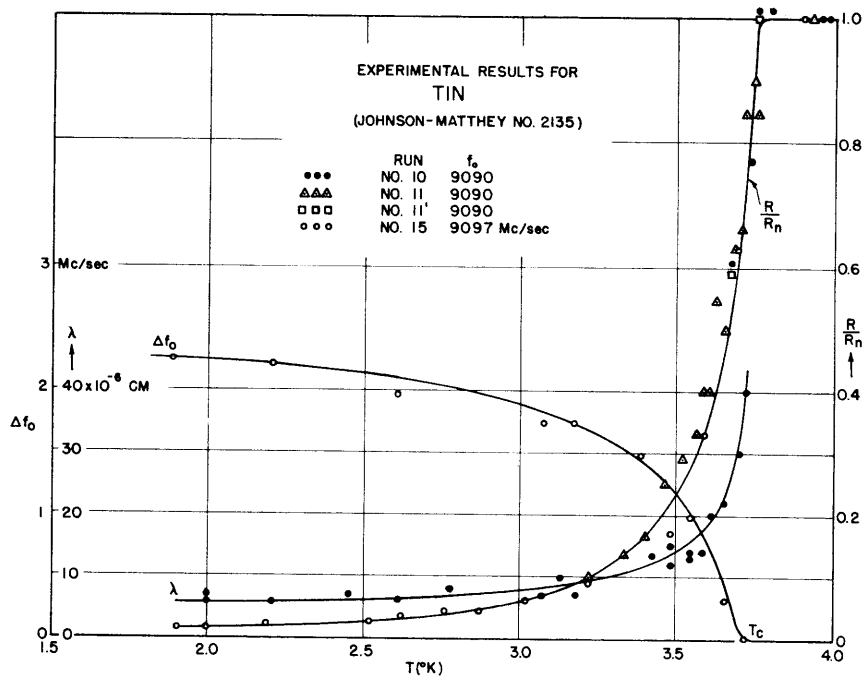


Fig. IV-1 Surface resistivity, frequency shift and penetration depth for superconducting tin as functions of temperature.

temperature from both measurements. This has been done by means of an extension of the Sondheimer and Reuther theory (1) to the superconducting state due to Marcus and Maxwell (2). The evaluation of experimental data was made on the assumption that the number of normal electrons remains constant through the transition ($f_n = 1$). The theory then gives

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$R/R_n = I(\beta)/I(0)$, where the function $I(\beta)$ of the parameter

$$\beta = \frac{27}{16} \delta_n^2 \lambda^{-2} f_n^{-\frac{4}{9}}$$

was computed and tabulated by P. M. Marcus. The quantity δ_n is the skin depth just above the transition temperature. As a check of this theory, the measured values of R/R_n were replotted in a logarithmic scale as a function of the dimensionless quantity $t = (T_c - T)/T_c$ and then slid along the horizontal axis until a fit with the theoretical curve was obtained. The shift of both scales determines β as a function of temperature T (Figure IV-2).

Most of the results were obtained with small quarter-wavelength coaxial resonators (2.05 mm-O.D., 3.40-mm I.D., 7.50-mm length) which were cast in vacuo in a glass mold. This final form of resonator proved entirely satisfactory. The surface was perfectly smooth and clean and there were no

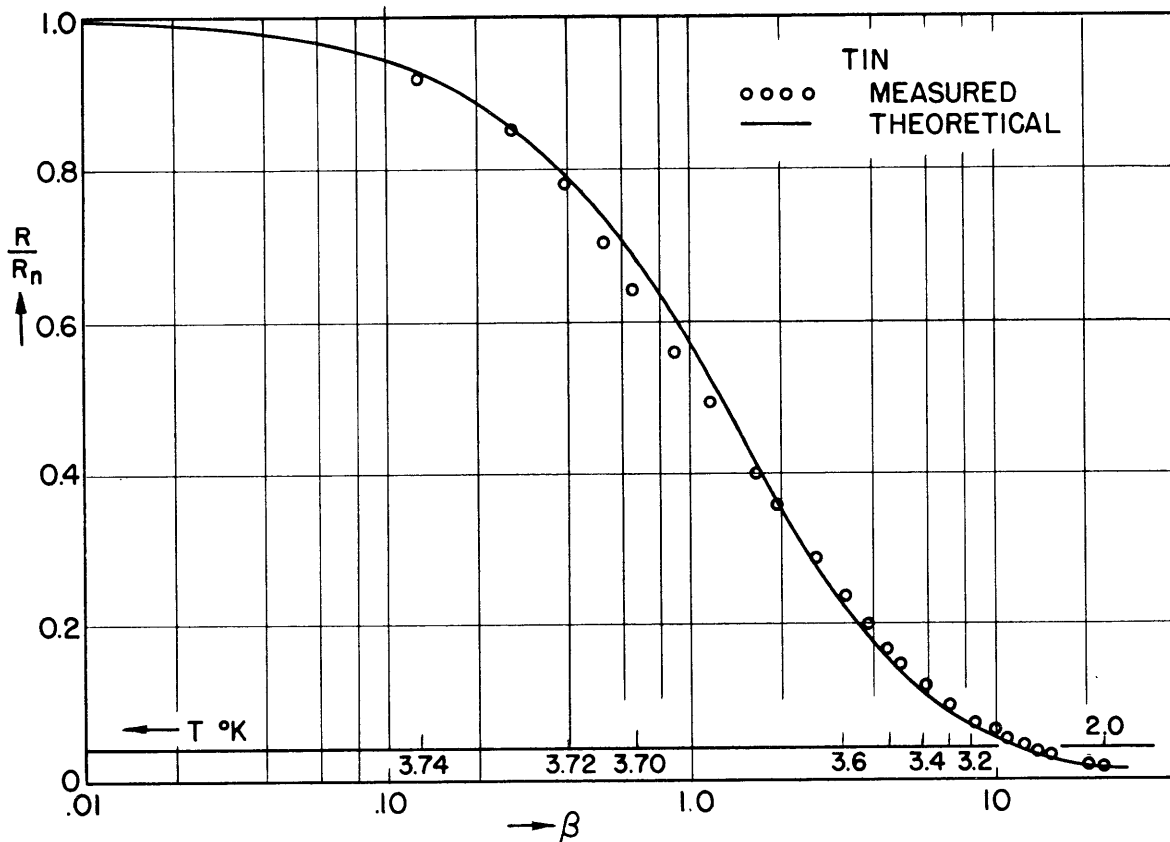


Fig. IV-2 Theoretical and measured surface resistivity of superconducting tin.

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supports, joints or machined parts inside the resonator. In the same way, some lead coaxials were prepared; a similar type of resonator is now being used for surface impedance measurements on frozen mercury.

A simple device was set up for keeping constant the pressure of the helium vapor in the cryostat during measurements. A relay-type bypass valve in the pumping line is operated by means of a thyatron and a differential mercury manometer. Preliminary tests showed that the pressure oscillations occur with a frequency of about 2 to 5 c/s and an amplitude adjustable to less than 0.5 mm Hg.

E. MAGNETIC COOLING

In the last quarterly report we announced the beginning of a program to develop magnetic-cooling techniques as an addition to the facilities of the laboratory. Apparatus has been constructed and tested during the preceding three months with the results given below.

In order to begin our work with the simplest possible apparatus, we used a scheme originally suggested and used by Kurti and Simon (3) in which a paramagnetic salt is sealed-off in a glass tube with a low pressure of helium transfer gas. The isothermal heat of magnetization is conducted into the liquid-helium bath by the transfer gas, but this gas is absorbed during demagnetization, leaving the process practically adiabatic. The flow of heat by thermal contact of the corners of the salt crystals with the glass tube immersed in the liquid helium bath is very small.

The measurement of temperature was accomplished by measurement of the susceptibility of the salt, using mutual inductances and a ballistic galvanometer -- again, initial simplicity of the apparatus taking precedence over refinement of the experiment.

Three experiments were performed with successive increases in magnetic field. The first, at 2,400 gauss, reached 0.25°K ; the second reached 0.1°K with 6,800 gauss, and the third reached 0.024°K with 30,000 gauss. The latter was accomplished with the facilities of the magnet laboratory kindly made available by Prof. Bitter. In each case, the initial temperature was between 1.5 and 1.6°K , limited by the pumping system of the liquid-helium Dewar. The salt used was ferric ammonium alum.

Apparatus has been constructed to improve the pumping speed and, therefore, to lower the initial temperature of the liquid helium bath. A Distillation Products type MB100 metal booster pump with a speed of 100 liters per second, backed by a 200-liter-per-minute forepump, was connected to the Dewar by a large pipe (four inches diameter). By over-

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volting the pump (a practice which is made economical by the use of comparatively expensive liquid helium in the same experiment), sufficient pumping speed was obtained to provide a helium-bath temperature of 0.87°K . This arrangement provides slow initial temperatures in a bath containing a large amount of liquid helium in a standard Dewar, as compared with the usual technique of cooling a very small amount of liquid helium by pumping through a capillary designed to reduce the heat loss by evaporation of the Rollin film. Demagnetization experiments have not yet been performed using this apparatus for the initial cooling.

A refined method of measuring the magnetic susceptibility is being developed so that more accurate readings may be taken. Also, the use of diluted potassium chrome alum to obtain lower "Curie" temperatures is being explored.

F. ELASTIC AND INELASTIC BEHAVIOR OF METALS AT LOW TEMPERATURES

Prof. Bordoni has completed this program, and the results will be published shortly.

G. X-RAY STRUCTURE OF SUPERCONDUCTORS

Prof. Tisza has suggested that small structural changes may take place in superconductors below their transition temperatures. Apparatus is being designed to allow study of the x-ray diffraction patterns of samples at liquid-helium temperatures as a possible means of observing such changes.

References

- (1) Sondheimer and Reuther, Proc. Roy. Soc. A195, 336, (1948).
- (2) P. Marcus and E. Maxwell, R.L.E. report in preparation; E. Maxwell, Ph.D Thesis in Physics, M.I.T., 1948.
- (3) N. Kurti and F. Simon, Physica 1, 1107 (1934).
