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SS-10 SUPERCONDUCTIVITY

In this experiment the magnetization of a typical type I and type II superconductor (Pb and $Pb_{85}In_{15}$) are measured at 4.2 K as a function of applied magnetic field. In addition the I-V characteristic of the type II superconductor is explored at various applied magnetic field strengths.

Pb: Measure the magnetization of the Pb sphere from H=0 to beyond H_c at 4.2 K. Discuss the shape of the magnetization curve in terms of demagnetization effects. By measuring $H_c(T)$ at lower temperatures, an estimate of T_c can be made.

$Pb_{85}In_{15}$: a) Measure the magnetization of the $Pb_{85}In_{15}$ sphere to H_{c2} at 4.2 K. Observations should be made for one complete irreversible cycle of the magnetization curve. Measure H_{c1}, H_{c2}, and H_c. Calculate the Ginsburg-Landau parameter κ several ways.

b) At 4.2 K measure the I-V characteristic of the short straight wire sample of $Pb_{85}In_{15}$ in a transverse magnetic field. Discuss the origin of the finite resistance observed below H_{c2}.

References:

Rose-Innes, Low-Temperature Techniques
Lynton, Superconductivity
Rose-Innes and Rhoderick, Introduction to Superconductivity

Notes for SS-10

I. Handling Liquid Helium

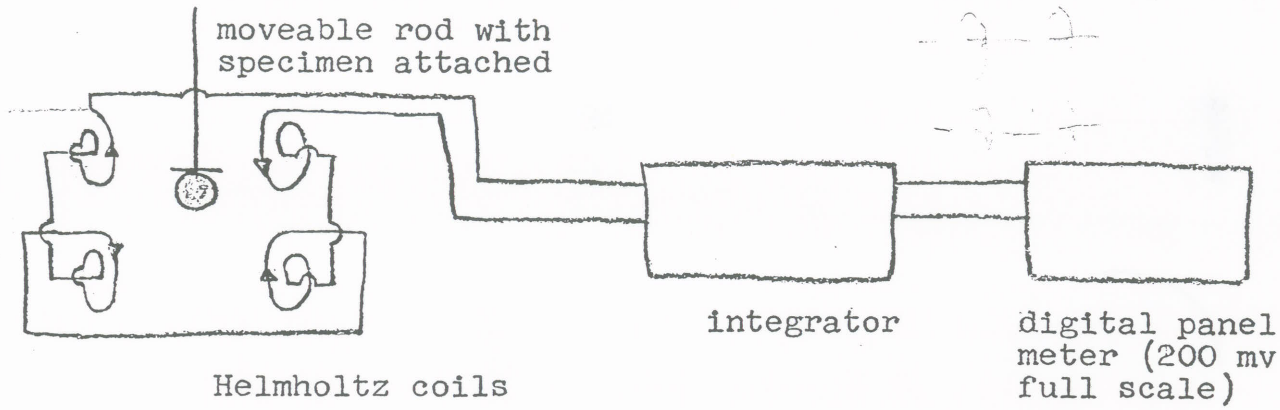
Liquid helium is stored for use in 50 l moveable dewars located in room H-19 in the basement. Your instructor will tell you the procedure for signing out these dewars, and the method used for determining the liquid level. Before beginning the experiment, precool the outer glass dewar at the experimental station by filling with liquid nitrogen. This should be done several hours before transferring liquid helium to give the inner dewar (as well as the specimen and its holder) a chance to equilibrate with the nitrogen bath. At this time one should also evacuate the inner dewar if this has not already been done, to avoid condensing air and water on the inner walls. To transfer liquid helium from the storage dewar to the inner glass dewar, a U-shaped transfer tube with an insulating jacket is used, and the liquid is forced from the storage dewar by means of modest gas flow from the helium cylinder. Before transferring, it is a good idea to run a little helium gas through the transfer tube to eliminate the possibility of blockages occurring, and to backfill the inner dewar with helium gas to atmospheric pressure. With the present dewar arrangement the transfer tube does not extend very far into the inner dewar even when nearly touching the bottom of the storage dewar; consequently, a rather fast transfer rate should be used to cool the narrow tail section of the dewar between the pole pieces of the magnet. typically about 3 or 4 liters of liquid are required to fill the dewar approximately two-thirds full. Generally, the instructor should be present when transferring. Although the procedure is basically simple, a 'soft' vacuum jacket in the inner dewar or transfer tube could cause a lot of liquid to be wasted. At the present price of $2.50/l, use of more than just a few liters can be expensive. After finishing the experiment (generally the liquid will last for a number of hours), the vapor pressure of the helium bath should be reduced by means of the vacuum pump located in the utility corridor (the switch is on the wall) and left with the pump operating. After the liquid has evaporated, the dewar is thus left evacuated. If this is not done, helium gas will remain in the dewar, and will diffuse through the glass into the vacuum jacket, eventually destroying its vacuum.

II. The Experiment

The principle underlying the measurement of the magnetization of the superconductor is as follows: The specimen (a sphere) is attached by means of copper wire to a moveable rod in such a way that it can be moved from the geometrical center of one set of Helmholtz coils to that of another. These two sets of coils are would in series opposition, and are located in the field of an electromagnet. As the specimen is moved from one set of coils to the other, the flux linked by the circuit is changed, inducing an emf at the coil terminals. By integrating the emf electronically, the flux change $\Delta\Phi$ is measured. It is not difficult to show that $\Delta\Phi$

is proportional to the magnetization of the specimen. Because of the complicated coil geometry, only relative values of the magnetization can be measured with this set-up.

A schematic of the electronics is shown below.



Each coil consists of 1250 turns of #40 Formvar-insulated copper wire and is 1/8" thick and approximately 1/2" in diameter. Although this information is not needed for the experiment, it would be useful if one of the coils should become defective. The series resistance of the four coils is approximately 500 Ω at room temperature and about 4 Ω at liquid helium temperatures. A schematic of the integrator is included with these notes. There is provision for resetting to zero, nulling drift in the output, and dividing the output by ten, should the need arise. The unit is calibrated--that is, the relationship of the output to input is known and is indicated below the circuit diagram.

A handbook for the operation of the electromagnet can be found at the experimental station. It is straightforward to use. Basically one should remember to turn on the cooling water and to set the regulator switch on 5 before turning on the power. If the latter isn't done, a number of resistors in the regulator will overheat, burn up, and cause damage to the regulator. After the power is on and the rough field value is selected, the regulator can be switched to the position that puts it in regulation range. This gives the most stable field. However, in this experiment field stability is not very important, and it is convenient just to leave the regulator switch at 5. This has the advantage of allowing one to increase (or decrease) the field in a monotonic fashion by means of the power supply control. This latter feature is very important for the type II superconductor which exhibits hysteresis.* The applied field can be measured by integrating the output of a calibrated flip coil (the calibration is on the coil) as it is moved out of the magnetic field. (At this point the fact that the integrator is calibrated is essential.)

Finally, the measurement of the I-V characteristic of the superconductor is made in a short, straight specimen, identical in composition to the specimens used in the magnetization part of the experiment. For this a 10 A current source (operated on a 12 v auto battery) and a Keithley millimicrovoltmeter are used.

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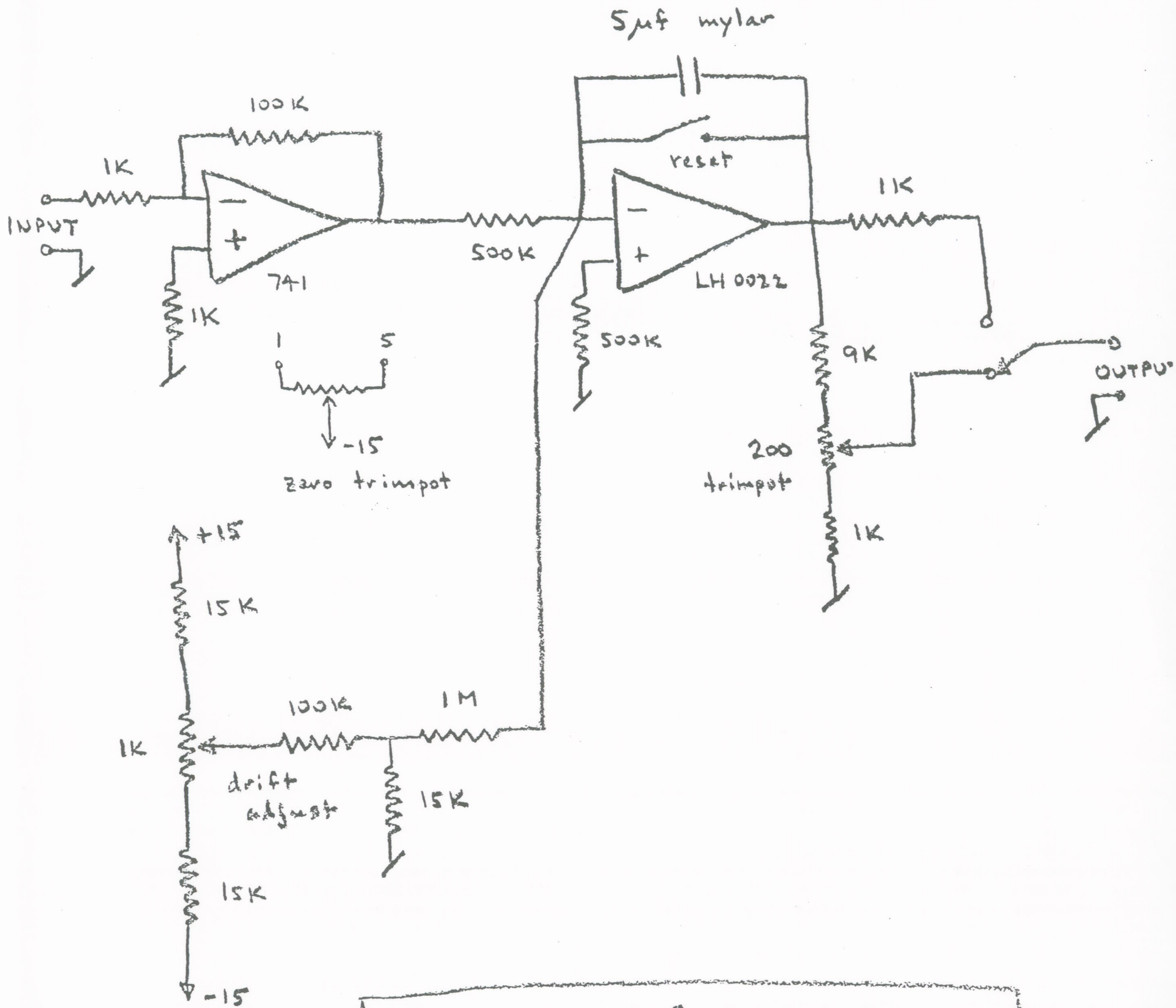
5/12/75

*Because of this hysteresis, it is important to start the experiment with a virgin specimen--that is, one that has been cooled through its transition temperature in the absence of a magnetic field.

Circuit Diagram of Integrator



$$V_{out} = \frac{1}{RC} \int dt \, V_{in}$$

$$\frac{1}{RC} = 36.4 \pm 0.2 \quad \text{sec}^{-1}$$