Superconducting Transition of Lead

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New measurements of the superconducting transition temperature of lead have been made ancillary to the redetermination of the absolute scale of thermoelectric power of this metal. Rather precise measurements on zone-purified lead give a transition temperature of 7.175±0.005°K in zero field which is lower than the previously accepted value of 7.22°K. The observed transition width was less than 0.001°K.

THE currently accepted superconducting transition temperature of pure lead in zero field comes from the work of Boorse *et al.* (1950)[1] who found a mean transition temperature of 7.22°K. In the course of a series of measurements of the absolute thermoelectric power of lead against the superconducting alloy Nb_3Sn,[2] we have repeatedly found the transition temperature of lead to lie somewhat lower than this value. We have therefore made rather accurate measurements of the transition temperature of the zone-purified lead (kindly supplied by Dr. A. Rosenberg of the University of Toronto[3]) which was used in the thermoelectric measurements. We find from three series of measurements that this zone-purified lead has a mean transition temperature of 7.175±0.005°K and a transition width of no more than 0.001°K, which is significantly less than the width of 0.04°K observed by Boorse *et al.* Because of the lower transition temperature found in the present experiments we measured the earth's field at the site of the apparatus finding 0.42 oersted. Such a field would result in a depression of the transition point by about 0.0016°K.

The transition was detected by an ac method using the magnetic induction at 800 cps between two small coils wound directly on the cylindrical specimen (dimensions 0.5 cm diameter, 2.0 cm long), the ac field being about 0.05 oersted.

The width of the transition was determined with a carbon resistance thermometer and the transition temperature was measured using two helium gas thermometers (volumes about 4.5 and 18 cc) filled to a pressure of about 18 cm of butyl-phthalate (∼14 mm of mercury). Two different-sized thermometer bulbs were used as this affords a means of guarding against the use of an incorrect correction for "capillary immersion" referred to below. At any particular temperature we made certain that the larger gas thermometer had reached equilibrium, which could take up to an hour. In order to determine temperatures accurately by this method a correction must be applied for an error due to the immersion in liquid helium of part of the gas thermometer capillaries. This correction can be estimated from the known dimensions of the capillary, but we were also able to determine it experimentally by including a sample of Nb_3Sn (superconducting transition centered at 17.95°K) in the cryostat. The gas thermometer pressures corresponding to the center of the Nb_3Sn transition were determined at two different capillary temperatures. This was achieved by using (a) liquid helium, and (b) pumped liquid hydrogen as the refrigerant. The pressure differences in the two conditions (about 1 cm for the smaller thermometer) allowed the effective capillary volume to be calculated and this agreed well with that estimated from the known dimensions of the tubing.

As a check on the accuracy of the gas thermometer scales, we measured the boiling and triple points of hydrogen of known ortho-para ratio (determined by a vapor pressure thermometer containing very pure hydrogen of "room temperature equilibrium" composition). In two separate experiments the temperature given by both gas thermometers lay well within 0.01°K of the accepted values for the "fixed points" of hydrogen of the appropriate ortho-para ratio, so we may with some confidence estimate the error at the lead point to be less than 0.005°K. The temperatures of the helium and hydrogen points were taken from the collected data of Linder.[4]

[1] Boorse, Cook, and Zemansky, Phys. Rev. **78**, 635 (1950).
[2] Christian, Jan, Pearson, and Templeton, Proc. Roy. Soc. (London) (to be published).
[3] The freezing characteristics of the lead after zone-purification showed it to be noticeably purer than the 99.999% Johnson-Matthey "specpure" starting material. The resistance just above the superconducting transition was about 8×10^{-4} of the resistance at room temperature.
[4] C. T. Linder, Westinghouse Research Report R-94433-2-A (unpublished).