## Superconductivity at Very High Pressures

19 000 atm., which we write as 17  $500\pm1500$  atm. We believe the results may fairly be stated as follows :

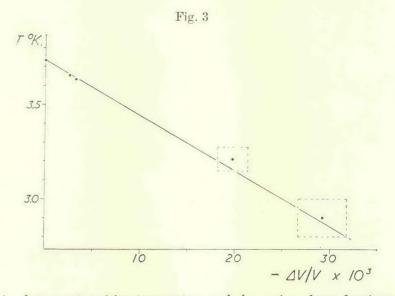
At 1 atm., the value of  $T_c$  determined by us agrees with the normal value  $(3.73^{\circ}\kappa)$ , within experimental error.

At 11 500 $\pm$ 1000 atm.,  $T_c = 3.21 \pm 0.07^{\circ}$ K.

At 17 500 $\pm$ 1500 atm.,  $T_c = 2.9 \pm 0.1^{\circ}$ K.

It is important to emphasize that the curves represent reversible behaviour and the effects shown are therefore not due to work-hardening (or 'cold-working'). After relaxing the pressure the curve obtained with a given specimen is indistinguishable from that obtained before the application of pressure.

Combining these with the results of Kan, Sudovstov and Lazarew (1948), and making use of Bridgman's values (Bridgman 1949) for the compressibility of tin, it is possible to plot  $T_c$  against  $\Delta V/V$ , where  $\Delta V$  is the change in volume due to the increase in pressure. This is done in fig. 3, where it



Relation between transition temperature and change in volume for tin under pressure. The areas enclosed by the dotted lines indicate the estimated experimental uncertainty in the present work.

may be seen that the variation is linear, within experimental error, and that the earlier and the present results lie on the same line.

The relation derived from the graph is

 $T_c$  (°K)=3.73+29 ( $\Delta V/V$ )

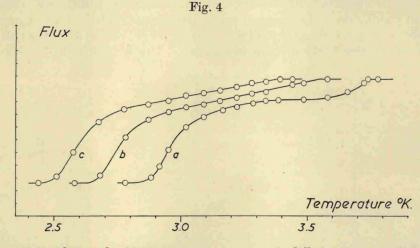
where the coefficient of  $\Delta V/V$  may be in error by  $\pm 10\%$  at the lower pressures and by  $\pm 20\%$  at the higher pressures.

We have also observed transitions under the highest of these pressures for a number of differing values of magnetic field (in the plane of the disc).

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The curves obtained are shown in fig. 4. A field of 50 gauss depresses the foot of the curve by about 0.37°. The corresponding depression at 1 atm. (see for instance Shoenberg 1952) would be  $0.35^{\circ}$ . Thus the quantity  $dH_c/dT$  at the temperature  $T_c$  remains substantially constant under pressure. At a given temperature  $H_c$  is of course lowered by pressure.

The magnitude of the quantity  $H_0$ , equal to  $(H_c)_{T=0}$ , is of theoretical significance since it is related to the difference in energy between the normal and superconducting states at absolute zero. Our experiments have not yet been carried to a sufficiently low temperature to determine the form of the curve of  $H_c$  against T, but we may point out that if it has



Transitions of tin under 16 000 atm. mean pressure in differing magnetic fields : (a) zero field, (b) 23.6 gauss, (c) 47.2 gauss. Flux in arbitrary units.

the approximately parabolic form characteristic of tin at 1 atm., then the present results imply that  $H_0$ —and therefore the energy difference between the normal and superconducting states—is lowered by compression.

## Lead

We have confirmed that  $T_c$  for lead is lowered by compression, but have not yet obtained detailed results on this metal.

## Thallium

Because of the anomalous behaviour reported for thallium by the previous workers (Kan, Sudovstov and Lazarew 1949), using resistance measurements, we have investigated it by our method up to higher pressures.

In two runs under mean pressures of 11 700 atm. and 13 400 atm. respectively, no signs of superconductivity could be observed above  $2\cdot35^{\circ}\kappa$  although an uncompressed specimen began to show superconductivity at  $2\cdot39^{\circ}\kappa$ . The whole transition curve was displaced by pressure

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