where

$$A=\frac{3B_k}{2}\,,\quad B=3-\frac{3Bk'}{4}\,,$$

and

$$Z=\left(\frac{V_0}{V}\right)^{1/3}.$$

V_0 is the volume at zero pressure and V the volume at pressure P. B_k is the isothermal bulk modulus and B_k' is its pressure derivative at zero pressure. At first, the volume change over a considerable pressure range is calculated from the use of appropriate B_k and B_k' using eq. (2). Here, they assumed that the linear variation of T_c with the volume change found from Swenson's data continues to hold up to 100 kbar. A least squares linear fit of ΔT_c to $\Delta V/V_0$ was then made to give $\gamma_s=(\partial \ln T_c/\partial \ln V)_{P=0}$. Having derived γ_s this may then be used to generate volume changes appropriate to a given change of T_c, which in turn may be substituted into the eq. (2) to obtain the corresponding pressures. In this way, the change of superconductive transition temperature as a function of pressure for tin was computed for 1 mdeg changes in T_c. We have used Smith *et al.*'s tin scale discussed above as a pressure manometer at low temperature. Then tin sample of 99.9% purity is rolled to a thickness of 0.03 mm and is annealed at 150°C, for 2 hours. Figure 7 shows the superconductive transition curve in each clamp load. The superconductive transition temperature is determined from the vapor pressure of liquid helium. The transition temperature is taken from the midpoint of the transition. The transitions are fairly sharp as shown in Fig. 7. From the sharpness of observed superconductive transitions, we considered that the homogeneity of pressure transmitting medium is fairly good. Figure 8 shows the change of superconductive transition temperature of tin *vs.* the clamp load. The agreement between the resistance and susceptibility measurements is fairly good. From these results, we were taken the pressure calibration curve as shown in Fig. 9.

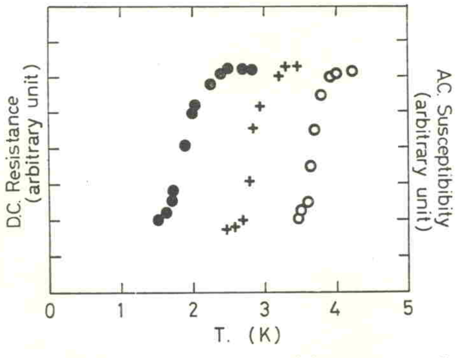

Fig. 7. Superconductive transition curve of tin at different clamp load.

○: non-compressed....a.c. method.
+: 0.8 ton load ......d.c. method.
●: 2.6 ton load ......a.c. method.

The effects of differential thermal contraction coupled with changes in elastic properties have caused the pressure to drop appreciably with temperature. At low temperature, the pressure loss is about 25%.

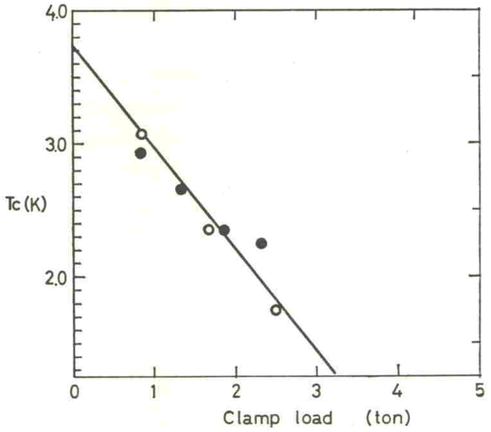

Fig. 8. Load dependence of superconductive transition temperature of tin.

●: d.c. resistance measurement.
○: a.c. susceptibility measurement.

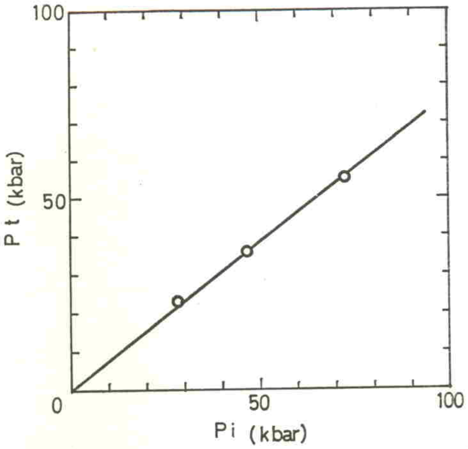

Fig. 9. Pressure calibration curve in the small Bridgman anvil (4.0 mm face) geometry;
P_i is the clamped pressure at room temperature.
P_t in the generated pressure at low temperature.

§ 5. Conclusion

The high pressure apparatus of clamp type was built. This apparatus was convenient to the high pressure experiment at low temperature because the experimental procedure is very simple and the consumption of liquid helium is very little because of its small heat capacity, that is 0.3 *l*/h. We have experimented the d.c. electrical resistance and a.c. mutual inductance measurement which are enough to detect the pressure dependence of the superconductive transition temperature of tin using the ferromagnetic tungsten carbide anvil (4 mm face) geometry. At room temperature, the pressure was generated up to 100 kbar using the small Bridgman anvil (4 mm face) geometry.

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References

1) J. W. Stewart: *Modern Very High Pressure Techniques* ed. R. H. Wentorf (Butterworths, 1962) p. 181.
2) J. E. Schirber: Phys. Rev. **140** (1965) 2061.
3) G. Fujii and H. Nagano: Cryogenics **11** (1971) 142.
4) P. F. Chester and G. O. Jones: Phil. Mag. **44** (1953) 1281.
5) W. Buckel and J. Wittig: Phys. Letters **17** (1965) 187.
6) J. Wittig: Z. Phys. **195** (1966) 215.
7) J. C. Wheatly: Rev. sci. Instrum. **35** (1964) 444.
8) N. B. S. Symposium (1968) "*Accurate Characterization of High Pressure Environment.*"
9) C. A. Swenson: *Metallurgy at High Pressure and High Temperature* ed. K. A. Gschneidner, M. T. Hepworth and N. A. D. Parlee (Gordon and Breech, 1964) p. 190.
10) T. F. Smith, C. W. Chu and M. B. Maple: Cryogenics **9** (1969) 53.