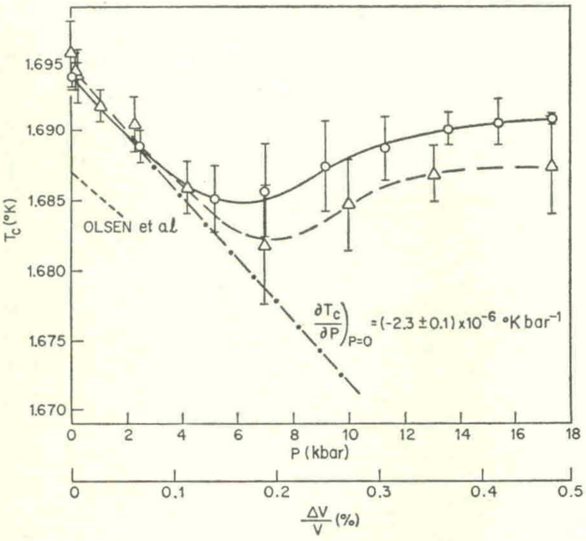

FIG. 2. Pressure dependence of T_c for polycrystalline Re. △ is Re2P; ○ is Re5P.

which froze (≳7 kbar) at room temperature during the pressure application. This produced broadened transition curves and clearly illustrated the sensitivity of the rhenium transition to nonhydrostatic conditions.

The transition to the superconducting state was detected by an ac bridge technique with a single frequency of 150 cps. After suitable amplification and rectification the bridge output was displayed on the Y axis of a X-Y recorder. The X axis was driven from the voltage drop across a germanium resistance thermometer which was calibrated against the 1958 He^4 vapor-pressure scale of temperature on each run. The uncertainty associated with the temperature was better than 0.5 mdeg. The pressure could be determined to about ±2%.

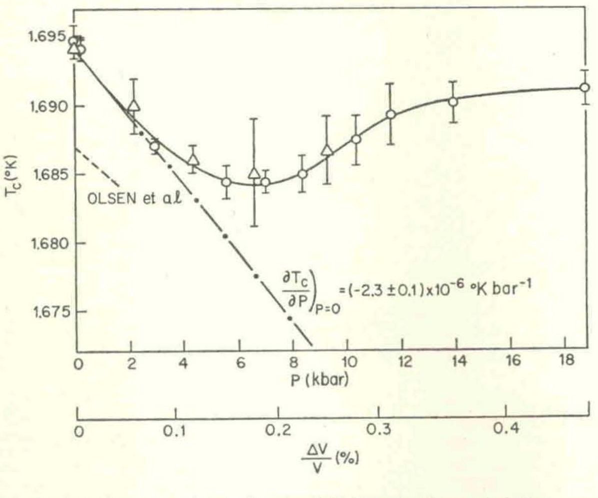

FIG. 3. Pressure dependence of T_c for single-crystal Re. △ is Re5S; ○ is Re4S.

EXPERIMENTAL RESULTS

Rhenium

Zero-pressure transition temperatures for five single-crystal and five polycrystal samples are listed in Table I. From these determinations the mean value of T_c, as represented by the midpoint of the transition, is (1.695 ±0.001)°K, in very good agreement with the values reported by Hulm and Goodman[10] and Blanpain[11] but slightly lower than the recent value of Maxwell, Strongin and Reed.[12]

Detailed plots of T_c as a function of pressure for two polycrystalline and two single-crystal samples are shown in Figs. 2 and 3. It can be seen that T_c decreases initially, passes through a minimum, and then levels off at about 17 kbar. The results for Re 5P, Re 4S, and Re 5S are in good quantitative agreement. Re 2P exhibits an over-all behavior which is similar to that of the other Re samples, but the minimum in T_c occurs at a slightly higher pressure. This is possibly due to contamination with tungsten (50 ppm atomic would be sufficient) during arc melting. This explanation would be consistent with its slightly higher zero pressure T_c.

The low-pressure ice-bomb measurement of Olsen *et al.*[13] is also indicated in Figs. 2 and 3. In view of the large uncertainty given in this previous determination their result is not inconsistent with the initial slope of $(-2.3 \pm 0.1) \times 10^{-6}$ °K bar^{-1} obtained from the present measurements.

Rhenium Alloys

The zero-pressure superconducting transition temperature as a function of concentration for the solid solutions of Os, W, and Mo in Re is shown in Fig. 4. The T_c increases slightly over the limited range of Re-W and Re-Mo alloys examined, but in the case of

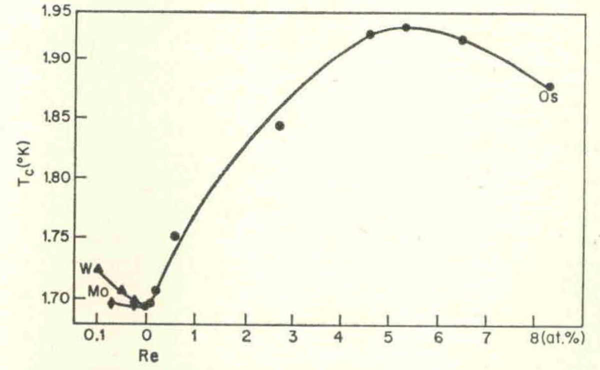

FIG. 4. T_c for Re alloys. ●, Re-Os; ▲, Re-W; ◆, Re-Mo (note change of scale from left to right of Re).

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[10] J. K. Hulm and B. B. Goodman, Phys. Rev. **106**, 659 (1957).

[11] B. Blanpain, Bull. Acad. Roy. Belg. Class Sci. **47**, 750 (1961).

[12] E. Maxwell, M. Strongin, and T. B. Reed, Phys. Rev. **166**, 557 (1968).

[13] J. L. Olsen, K. Andres, H. Meir, and H. de Salaberry, Z. Naturforsch. **18a**, 125 (1963).

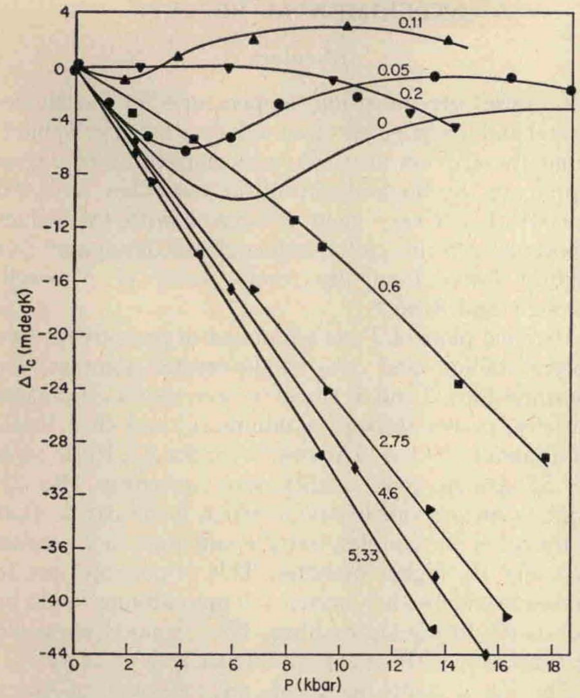

FIG. 5. ΔT_c as a function of pressure for Re-Os alloys. The number associated with each curve represents the at.% concentration of Os.

the Re-Os alloys, T_c passes through a maximum at ~5.5-at.% Os. This behavior of T_c for the Os alloys is in contrast to that of the density of states, which decreases continuously over this composition range.[14]

The pressure induced change in T_c, ΔT_c, for the alloy systems is plotted as a function of pressure for several compositions in Figs. 5–7. With the addition of Os, the pressure P_m at which the minimum of the $\Delta T_c(P)$ curve occurs was found to move towards lower pressure and disappear when the Os concentration reaches 0.2 at.%. For concentrations greater than 2.75-at.% Os, T_c decreases almost linearly with pressure. It is of interest to note that the sensitivity to pressure inhomogeneity observed for the transition for pure Re was found to be absent in alloys with Os concentrations in excess of 0.6 at.%. The addition of W causes P_m to move rapidly to higher pressures. Thus, the addition of 0.1-at.% W raises P_m from 6 kbar to a value in excess of 18 kbar. Mo is less effective in raising P_m, and P_m shows very little change between 0.02 and 0.07-at.% Mo.

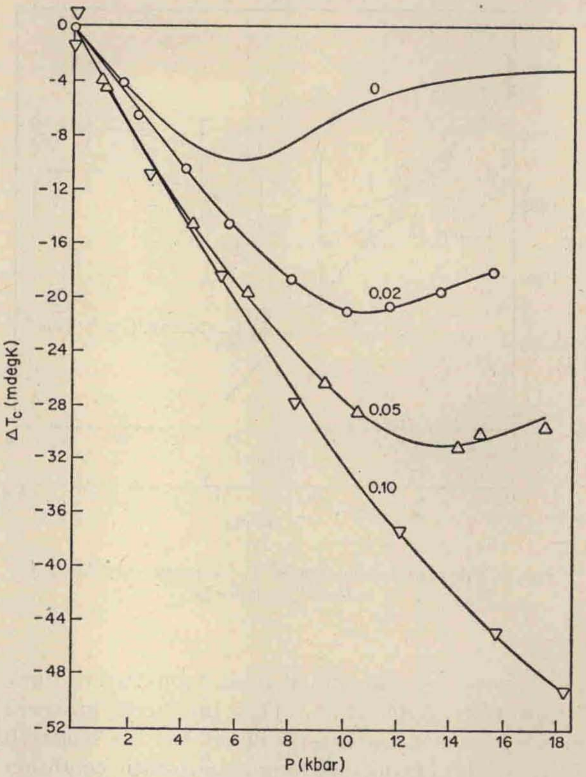

FIG. 6. ΔT_c as a function of pressure for Re-W alloys. The number associated with each curve represents the at.% concentration of W.

DISCUSSION

We propose to adopt the approach of Lazarev and co-workers[5] and regard the anomaly in the behavior of T_c as a function of pressure as being composed of two parts, one of which is the normal linear variation of T_c with pressure, and the other, a nonlinear contribution which is associated with an abrupt change in the Fermi-surface topology.

Abrupt changes in Fermi-surface topology are related to critical points in the $E(\mathbf{k})$ spectrum.[15] Such critical

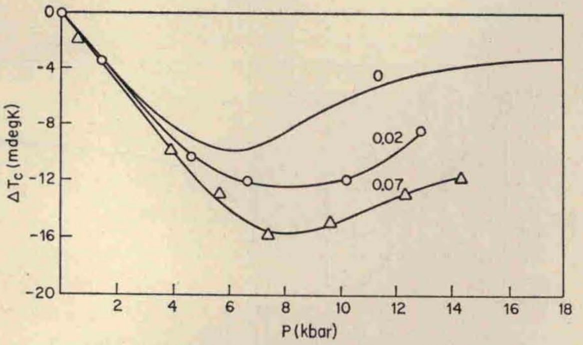

FIG. 7. ΔT_c as a function of pressure for Re-Mo alloys. The number associated with each curve represents the at.% concentration of Mo.

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[14] E. Bucher, F. Heiniger, and J. Muller, in *Proceedings of the Ninth International Low-Temperature Conference, Columbus, Ohio,* edited by J. G. Daunt *et al.* (Plenum Press, New York, 1965), p. 1059; J. P. Maita (private communication).

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