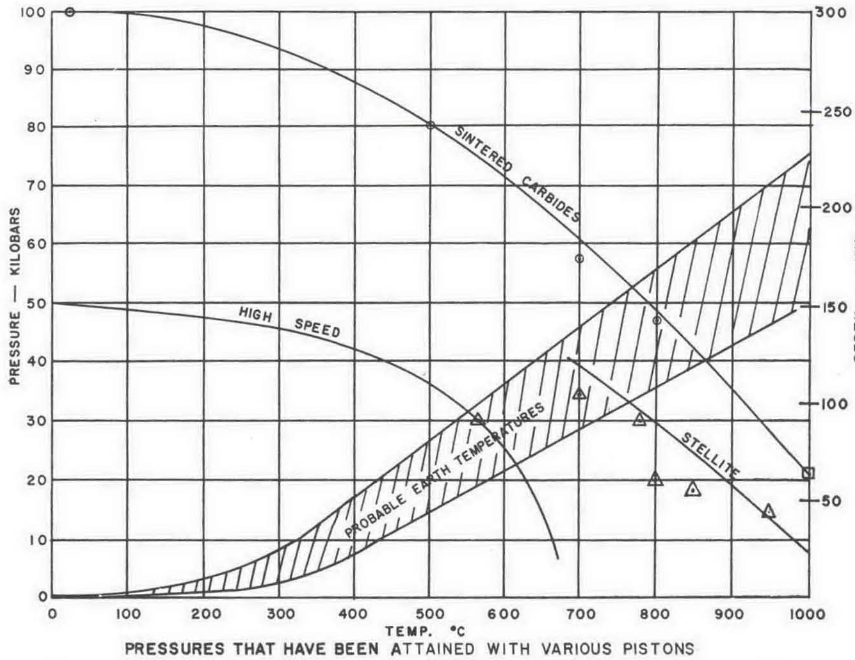

Fig. 3. Maximum working pressures that have been attained. In many of the points, no piston damage was observed. The Earth temperatures correspond to a surface heat flow of 1.2 x 10^{-6} cal/cm^{2}sec, 2/3 to 3/4 originating in a 30 km crust, and a conductivity in the mantle of .008 cal/cm sec deg.

invariably appears after any run at 50-60 percent of the maximum pressure to which the pistons are usable. They are initially very fine radial cracks, and after repeated runs at higher pressures they gradually widen. Destructive fracture in carbide pistons of the type shown in figure 2-A occurs after very appreciable plastic flow has occurred and may occur in a test at considerably lower pressure than the piston has already withstood. Such fracture most commonly takes the form of shear on an inverted 45° cone, passing through the outer boundary of the piston face. This shear is typically associated with radial cracks external to the cone, and occasionally with spalls.

Stellite and High Speed Steel have much less tendency to crack and frequently their life is terminated simply by excessive flow. When destructive fracture does occur, it follows the pattern of the carbide pistons.

Both types of pistons show appreciable dishing after runs approaching the maximum pressure. Figure 4 shows the profile of one pair of Kennametal K-6 cemented tungsten carbide pistons after several runs at 500°C, at a maximum pressure of 80 kb. These pistons have made many more runs at high pressure.

This dishing has no deleterious effect so far as we have been able to learn. On the contrary, it has two beneficial effects: (1) the central pressure is more uniform due to steeper pressure gradients at the periphery; (2) the sample thickness is greater—reaching .015″ in these pistons, independent of

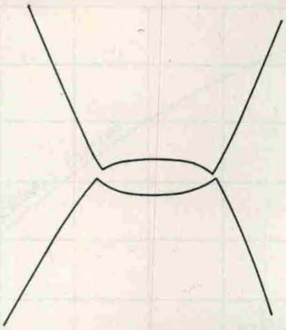

Fig. 4. Profile of Kennametal K-6 piston faces after several runs at 500° C-maximum pressure 80 kb (vertical exaggeration 5:1). Depression in center of piston face: .005″. Where pistons are not of same size, area of smaller one is used in calculating pressure.

pressure. With dished pistons an excess of sample is always used, to be sure of filling the space between the pistons at pressure.

For temperatures up to 600°C, pistons made of ordinary high speed steel provide respectable pressures.

Above 1000°C, pressures attainable with this type of apparatus may be expected to decrease to about 10 kb at 1200°C with the best materials available. For higher pressures at the higher temperatures, localized heating of the sample will be necessary, so that the pistons will be cool in regions of high stress. In principle, any desired temperature may thus be reached at 100 kb. Bridgman's (1952) resistance apparatus indicates one method by which electrical heating might be used.

Pushers are made of Inconel X. Transite was initially chosen for thermal insulation of the push rods after tests of other similar materials. At high temperature and pressure, transite deforms and must be frequently replaced. It has recently been found that the thermal insulation provided by the transite is unnecessary, and these parts are now made of stainless steel.

It is desirable to design the apparatus so that it undergoes large elastic strain at pressure, in order to reduce the pressure rise due to thermal expansion on heating. This is done principally by making the press tie-rods long and of minimum cross section. The apparatus shown in plate 1 increases in pressure about 60 percent on heating to 600°C, due to the expansion of the pushers and piston holders which would amount to about 1/16 of an inch at constant pressure. Approximately one-third of the yield of the apparatus is extension of the tie-rods, one-third is compression of the pushers and piston assembly, and the remainder is due to bending of the end plates, compression of oil in the ram, etc.

It is necessary to water-cool the plate at the top of the ram to prevent heating of the oil in the ram, which would cause a rise in pressure. With this water turned off, a pressure rise at an initial rate of 50 percent per hour is observed after attaining a stabilized temperature. With the water on, pressure remains constant to a few percent.