Problems which have been studied in opposed-anvil apparatus, in addition to those of synthesis and phase equilibria, include kinetics of reactions, diffusion, orientation, influence of shearing stresses, crystallisation of glasses or gels. *In situ* measurements of various electrical properties have also been conducted. This broad range of problems is made possible in part by the fact that scaling-up of the size of the apparatus (in this laboratory from 8 to 400 tons) in no way affects the extreme simplicity of operation. The other major advantage which opposed anvil devices have over internally heated piston-and-cylinder apparatus is the accuracy of temperature measurement which is very greatly superior to that in other apparatus. Concomitantly, its greatest limitation is the unattainability of the higher temperatures possible with other apparatus.

Current design of anvils

Materials and shapes

Despite the great interest in high-pressure studies, very little fundamental work has been reported on the design of anvils. The development of this equipment has been based mainly on empirical experience gained through use.* Thus, in the selection of an optimum design of the simple piston, questions raised regarding the ratio of the diameter of the sample face to that of the body, or of diameter of the body to length, or of the angle of the cone, could not be answered by recourse to results of systematic studies.† Rather, a practical sequence of choices was made starting with a minimum sample size (6—10 mg.) determined by the requirements for *X*-ray and optical identification, which should be contained in the $\frac{1}{4}$ in. diameter wafer assembly shown in Fig. 1. An outside diameter of 1 in. was found to be very convenient insofar as centering and supporting on softer Stellite-25 thrust bars. The length of the anvil was determined by convenience and by length of the hot zone of the furnace used to heat the sample assembly. With regard to the cone angle, a broad one close to 180° might be a theoretical choice, but actually angles between 150° and 160° have been found best for most types of work. The larger angles provide enough space to position properly a thermocouple close to the sample. More important, the wider angle between the two anvils practically eliminates the interference with the calculation of pressure on the ' flat ' sample faces which is a very serious consequence of the unknown and variable extrusion of material.

If only from the observation of types of failure of the simple anvils, without being aware of earlier solutions, certain modifications of design would be sure to suggest themselves. In almost every case, simple pistons made of hardenable high temperature steels, 66HS (see appendix), Speed Star, polycrystalline alumina or mullite fail by breaking into three pieces, two being essentially equal halves and the other a small wedge having the sample area ' flat ' as a base (Fig. 3). On the occasions when the anvils do not fail completely, radial cracks will be found starting at the small end of the cone at the edge of the sample flat but very seldom crossing it. Apparently these cracks are caused by peripheral tension failure, and in many cases, occur just before the shear failures which produce the small wedges. Anvils of tungsten carbide fail with considerable shattering and spalling of the conical surface.

Bridgman's first step in improving the performance of anvils was to provide lateral support by compression in a holder, or by a combination of compression and tapered seat as shown in Fig. 4. With such support it has been possible to raise the effective pressure attainable with the special steels from 60 kb to 90—100 kb and with tungsten carbide (6% cobalt) the upper limits are 160—200 kb. Another advance is the graded support developed by Drickamer[4], whereby maximum reinforcement is provided at the region of maximum stress at the end of the cone. In a sense, Drickamer's modifications are intermediate between the simple anvil and the designs

* Prof. Bridgman told one of us (R.R.) that he had chosen his angles, shrinkage and other dimensions in the same empirical manner.

† Some idea of the changes in stress distribution with changes in design have been obtained in this laboratory from studies with simplified two-dimensional photoelastic models of anvils. Thus the influences of cone angle, diameter ratios, and diameter and length ratios have been studied in the stress patterns. The additions of lateral support and then of support to the conical shoulders produce remarkable redistribution of stresses which qualitatively are related to the increase in strength actually observed. More accurate but similar patterns may be obtained using three-dimensional models following a technique used by Stefanko & Tandanand (personal communication). The correlation between complex anvils made of dissimilar materials and the plastic models is not known, but it should be close enough to be instructive.