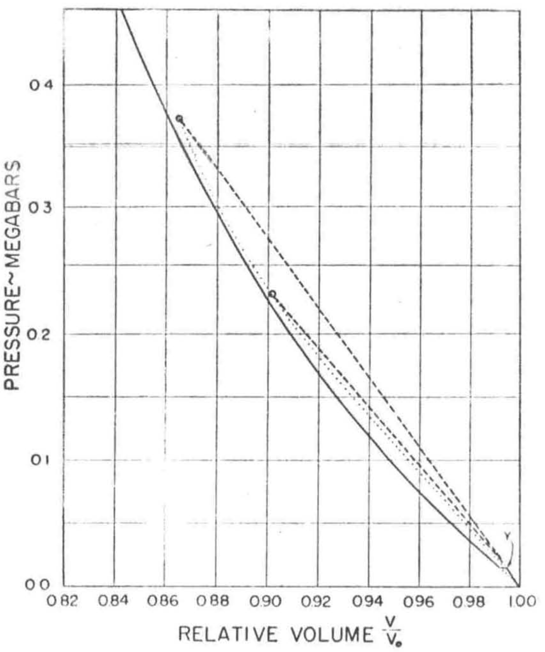

FIG. 2. Solid line represents a hypothetical isentropic equation of state of steel subjected to uniaxial compression, showing effect of shearing stress below the dynamic yield point Y. Shock wave velocity is given by the expression $D=(-\Delta p/\Delta V)^{\frac{1}{2}}V$, where V is the specific volume of the material ahead of the shock; Δp is the incremental shock pressure; and ΔV, the change in specific volume due to the shock.

Below the dynamic yield point, compressional waves are propagated with the sound velocity, proportional to the square root of the slope of the solid line.

Above dynamic yield point, compressional waves are propagated with velocities proportional to the square root of the slope of the dashed lines. By joining the end points of the dashed lines, one obtains the representation of the "Rankine-Hugoniot" equation of state shown by the dotted curve. This lies above the isentropic because of the entropy change under shock conditions. Upper dashed line represents a shock traveling with the velocity of sound at low pressures, i.e., a shock not preceded by an elastic wave.

is exceedingly abrupt and that the amplitude of this abrupt rise is constant provided the material behind the wave is uniformly compressed. Constancy of pressure behind the shock front may be achieved approximately by using a sufficiently large block of high explosive. If, however, the wave is not plane, its space configuration varies as it proceeds, and if the compression behind the front is not uniform, the magnitude of the virtually discontinuous pressure change is not constant. Furthermore, even if the wave is perfect in terms of the above criteria the plane of the waves may not be parallel to the plane of the plate. A variety of special precautions has been introduced to minimize effects of these possible sources of error. Continual improvement in the preparation of the H.E. and the "lens" have virtually eliminated departures from planeness and tilt in the wave itself. A small residual tilt of the front does not affect (to errors of the first order) the inferred velocities if the pins are properly arranged in small circles. In some experiments, as many as nine circles of eight pins each are used to supply simultaneous information.

In addition to the above difficulties it has been found that small irregularities or scratches in the surface of the plate result in jets which may cause erratic pin discharge. Indeed owing to the polycrystalline structure of the metal itself, some irregularities in the moving free surface are invariably present, the magnitude of these irregularities being of the order of the size of the individual metallic crystal grains. Because of this unavoidable roughness, it is not practical to make free surface velocity measurements over extremely short ranges of motion. Experiment has shown, however, that these irregularities are not too serious if the total range covered by the pins exceeds 5 mm.

A further limitation on the method results from the fact that in certain materials (e.g., steel) an elastic wave of compression moves with a higher velocity than the shock wave up to a certain pressure which depends on the dynamic yield point (see Fig. 2). In such cases, the necessary information can be achieved by the use of piezoelectric crystals (see Figs. 3 and 4).

One further technical experimental point deserves brief mention. As has been mentioned, some decay of pressure is encountered with increasing thickness of the plate. It is thus essential that the shock wave velocity and the mass velocity be obtained for an equivalent particle, namely a particle close to the free surface of the plate. But the probes for measuring propagation velocity are perforce distributed through the thickness of the plate, and, since the amplitude of the shock is varying, so also does the propagation velocity vary. The simplest way of finding shock velocity at the free surface is to make the portion of the plate where the shock velocity is measured somewhat thicker than the portion where the free surface velocity is measured, so that an average value for the former will be compatible with the observed value of the latter.

From the measured free surface velocity, the mass velocity of the compressed material may be inferred. It is, of course, necessary to complete the measurement of free surface velocity before reverberations can occur in the target plate. Otherwise, one obtains a measure not of mass velocity but of momentum transfer from explosive to plate. Furthermore because of the decay of pressure behind the shock front, one might expect the *observed* free surface velocity to diminish as the motion proceeds, but such an effect has not been detected. With these considerations in mind each set of 8 contactors is usually spaced over an interval of about 5 mm from the

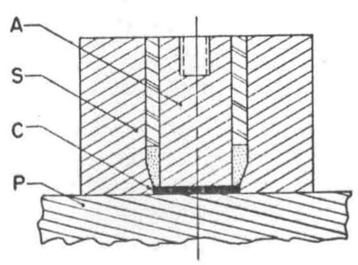

FIG. 3. Assembly for holding piezoelectric crystal in place. *A* Metal electrode and inertial support for crystal. *S* Guard ring. *C* Crystal. *P* Specimen through which shock-wave proceeds.