Only a limited amount of information is available for plastics in the stress range at which one expects nonhydrostatic effects to be appreciable. Poly methyl methacrylate (Plexiglas), however, has been studied by several investigators and it is reasonable to suppose that its behavior is typical of many polymers.[79-81] An excellent discussion of its high pressure behavior has been given by Deal.[82]

There are two distinctive features of the shock response of plexiglas that are in marked contrast to the behavior of metals or of brittle solids. An elastic precursor wave has never been observed even at low impact stresses, and evidently one does not exist.[79-81] The observed shock velocities, moreover, extrapolate to the longitudinal sound speed at zero stress. It is not reasonable to suppose that the shear stresses increase indefinitely with shock stress, although Ainbinder, et al, have observed an increase by nearly a factor of two in yield stress under confining pressures of about 2 kbar.[83] It may be that yielding occurs over a wide stress range so that a cusp in the P-V curve (Fig. 2) never appears. Measurement of release curves or comparison of shock data with hydrostatic data would provide valuable information about the shear stresses. Experiments on epoxy at stresses as low as 3.2 kbar also show no indication of an elastic wave.[84] That epoxy cannot be treated as a fluid is indicated by Erkman's data on shock decay.[58] (Fig. 19)

Plexiglas also exhibits pronounced relaxation of the shocked state with propagation distance in experiments in which rarefaction waves from boundaries cannot influence the shock front.[85] Thus, it is a highly rate-sensitive material.

Kolsky has devised a constitutive relation for polymers that successfully predicts the pulse shapes in plexiglas and polyethylene in the low stress range in rod or spherical wave geometry.[86] It is based on a viscoelastic model and employs an empirically determined value, assumed independent of frequency, for the phase angle between the stress and strain amplitudes in a sinusoidal wave. It would seem fruitful to attempt to apply his analysis to plane waves as well, and to try to extend it to include nonlinear stress-strain behavior.

V. CONCLUSIONS

The subject of one-dimensional-strain constitutive relations applicable to shock propagation, with the possible exception of high pressure equation of state measurements, is clearly in its infancy. As experimental techniques become more refined the concepts and assumptions of gas dynamics, such as discontinuous shock fronts and equilibrium, isentropic rarefactions, which formed the early foundation for the subject appear to lose pertinency. Certainly, the assumption of isotropic stress even at stresses very much in excess of the yield stress has been found to be questionable. Stress relaxation effects also seem to be very common.

Because of the often severe distortion of the shock structure by reflections at interfaces, the techniques which seem to hold the best promise for significant advances in understanding are those that can be imbedded in the material, such as piezoresistive gauges, electromagnetic velocity gauges, and, for transparent substances, optical methods. Quartz and sapphire gauges, of course, should be added to this list where the shock impedance of the sample is closely matched. These, combined with a general analytical treatment such as that outlined in Section III, should provide a sounder base of experimental information than currently exists.

The elastic-plastic model has been demonstrated to give reasonable predictions for metals when rate effects are not large and at stresses only moderately exceeding the yield stress. Rate effects are the subject of much current research and it may be expected that progress will be made in understanding not only such phenomena as the decay of elastic precursor waves, but, perhaps more importantly, the physics of the plastic shock transition itself. The behavior of the yield stress at higher pressures is clearly not well understood; whether or not it increases substantially with pressure and to what extent the Bauschinger effect is important are still controversial topics.

Brittle solids are even less well understood and one cannot predict with confidence whether for a given material substantial shear stresses can exist behind the "plastic" shock front, nor what the release paths from a