speed machines there is no barrier except cost to the most detailed comparison of shock structure with the predictions of various models. In this way extremely critical tests of theories of constitutive relations are possible.[29] Some use has been made of this capability, but its use is still limited--perhaps primarily by the scarcity of good physical models.

II. ACHIEVEMENTS

In 1963 Fowles and I attempted to collect references to all Hugoniot data that had been published and we found measurements on about eighty substances, not counting minor variations in composition of steel and aluminum.[30] In 1967 the Lawrence Livermore Laboratory issued a three volume, looseleaf compendium of shock wave data which contains entries for about 160 materials, with the same restrictions.[31] I doubt that the pace of data production has slackened; linear extrapolation from these two points suggests that the number of substances for which data are available today is about 300. Collection and publication of such data provides a real service to the technical community. The data are expensive to obtain and not easy to duplicate without special facilities. They should be made available to the general user.

In spite of the amount of data available, it turns out that few substances are well characterized over a large range of pressure. From the jump conditions one finds that the r.m.s. errors in pressure and compression in terms of particle velocity u and shock velocity D are

$$\delta p/p = [(\delta u/u)^2 + (\delta D/D)^2]^{1/2} = \delta(\Delta V/Vo)/(\Delta V/Vo)$$

Variations in arrival times of the shock over a free surface in the average experiment is probably not less than 50 nanosec over a 3 cm diameter specimen. If total travel time through the specimen is two microsec., the uncertainty in D is $\delta D/D \sim .05/2 = 0.025$. Measurements of u are probably better than this on the average, so the uncertainty in p and $\Delta V/Vo$ in the average published data point is probably 2.5 to 3%. It can be much more unless the work is done carefully. It can be appreciably less if the work is painstaking. As more measurements are published for a given material, one may expect the error in the mean Hugoniot curve to diminish.

The existence of good Hugoniot data on many materials has prompted much study of theoretical equations of state with the result that keener understanding of the compression process now exists, particularly for the rare earths and rare gases.[32]

In 1968 Jones and Graham published a table of elastic precursor measurements.[33] There were a hundred and thirty published measurements at that time, including duplicates and measurements on twenty different iron and steel alloys. The total has increased substantially since then, and it includes extensive series of precursor measurements in LiF made by J. Asay[34] and Y. Gupta.[35] As it presently stands, it is established that elastic precursors are indeed elastic waves. Their amplitude is directly related to the resolved shear stress which the material is supporting at the instant of measurement, and this amplitude decays as the wave propagates into the sample. The rate of decay is related to the dynamic failure of the material, and, in ductile materials, it can probably be related to the velocity and rate of generation of dislocations in the material, though this last statement must be labelled speculation at present. With some adjustment of parameters, a reasonable dislocation model can be used to fit most, but not all, of the measured shock profiles. Precursor decay measurements and the associated dislocation analysis have been made in lithium fluoride, tungsten, iron and aluminum, but not in other materials. Measurements at three different crystal orientations in tungsten strongly suggest that the slip mechanisms operating in shock loading are the same as those operating in quasistatic slip.[36] Electron transmission micrographs from recovered metal specimens suggest that the details of dislocation behavior in shocked materials may be quite different from those found in thin bar experiments, perhaps because of the very short distances travelled by dislocations during the shock process.[37]

In 1954 Stanley Minshall reported a 130 kbar "plastic wave" in iron which he tentatively identified as being due to a polymorphic phase transition induced by shock waves.[38] He tentatively identified this as the α-γ transition, but in a brilliant series of experiments which traced out the phase diagram in iron it was determined in 1961 to be a new phase,[39] later identified as hcp.[40] Since 1954 quite a number of solids have been found to undergo phase transitions under the influence of shock waves.[41] Shock transition pressure does not usually exceed the static pressure of transition, where static values are known. This is curious because the time available for transition is small and, since transitions are sometimes slow in occurring under static conditions, it might reasonably be assumed that they might not occur at all in a very short time, or that they might occur at higher pressures. This suggests that a study of the kinetics of phase transition under shock conditions may be fruitful. Calculations indicated that a finite transition rate produces a decaying wave similar to the elastic precursor resulting from dynamic failure[42] and that, if transition time is between 10^{-8} and 10^{-5} seconds, it can be detected in a shock experiment.