TABLE 3. Input Data Reduction Sets for Garnet hpp

Data Set	Initial Density, g/cm^3	α, °K^{-1}	Transition Energy, kb/g/cm^3	Initial K_0, Mb	Initial s	δ	Calculated K_0^S, Mb	Calculated $(\partial K^S/\partial P)_T$
*a**	4.44	23(10^{-6})	2.13	3.00	1.00	6.00	3.19	2.6
b	4.38						2.60	3.7
c		18(10^{-6})					3.19	2.6
d			1.07				3.09	2.9
e				2.50			3.19	2.6
f					1.50		3.19	2.6
g						4.00	3.23	2.3
h						8.00	3.16	2.9

*Basic data set of input parameters.

hydrostatic Hugoniot would be measured if the material retained zero strength upon shock compression.

A method for determining the stress offset from the Hugoniot elastic limit (HEL) has been suggested by *Fowles* [1961] and *Ahrens et al.* [1968]. It is assumed that the low-pressure phase behaves as a simple elastoplastic material. In this case the maximum shear stress $\tau_{\max}$ remains at the constant level reached at the HEL. The amplitude of the elastic precursor in a shock wave experiment represents the HEL and defines the maximum normal stress that the material can withstand under one-dimensional compression without shear failure occurring at the shock front. The elastic precursor stress amplitudes for the Salida garnet work are plotted in Figure 7.

The elastic precursor data were fit to a straight line by using a weighted least-squares procedure. The calculated slope is $dP/d\rho = 705 \pm 40$ kb/g/cm^3. The deformation accompanying a propagating planar shock front is one dimensional in the strain. In this case, along the shock front of the elastic precursor the stress-strain relation can be given by $P_1 = C_{11}^S\epsilon_1$, where C_{11}^S is the adiabatic second-order elastic stiffness coefficient of the garnet sample. In addition, since $\epsilon_2 = \epsilon_3 = 0$, it can easily be shown that, to first order in strain,

$$P(x) = C_{11}{}^S(1 - x) \qquad (17)$$

represents the elastic compression behavior. Moreover, if (17) is differentiated with respect to density and evaluated at $P = 0$, it is seen that $dP/d\rho = C_{11}/\rho_0$. By using this relation and the previously determined slope of the elastic precursor data, a value of 2.95 ± 0.08 Mb was calculated for C_{11}^S. This value may be compared with that of 3.04 ± 0.02 Mb calculated previously for this parameter from acoustic measurements. The elastic behavior of the precursor data is verified by this correlation. The calculated fit to the elastic precursor data, representing one-dimensional 'elastic' deformation, is also indicated in Figure 7.

It is apparent from Figure 7 that the HEL values achieved by the individual garnet samples occur over an extended range of stress levels. The reason for this behavior is not clear; presumably, it reflects a variation in the internal strength characteristics of the individual samples, possibly related to the occurrence and the texture of microfractures or impurity inclusions or both. For the present purposes an average HEL value was calculated to represent the general strength characteristics of the Salida garnet. A value of 81 ± 17 kb was computed by using a weighted average over pressure, including the 11 individual precursor stress levels. This HEL is indicated in Figure 7 and was used in determining the stress offset. A hydrostatic metastable Hugoniot appropriate for the Salida garnet was calculated by using the Hugoniot equation of state [e.g., *Wang*, 1969]

$$P(x) = \rho_0 C_0{}^2(1 - x)/[1 - s(1 - x)]^2 \qquad (18)$$

with C_0 and s values calculated from the acoustic data of *Soga* [1967]. The trace of the Salida garnet hydrostatic Hugoniot is shown in Figure 7. The corresponding stress offset between the average HEL and the hydrostatic Hugoniot is $\Delta P_H = 27 \pm 7$ kb. The average maximum

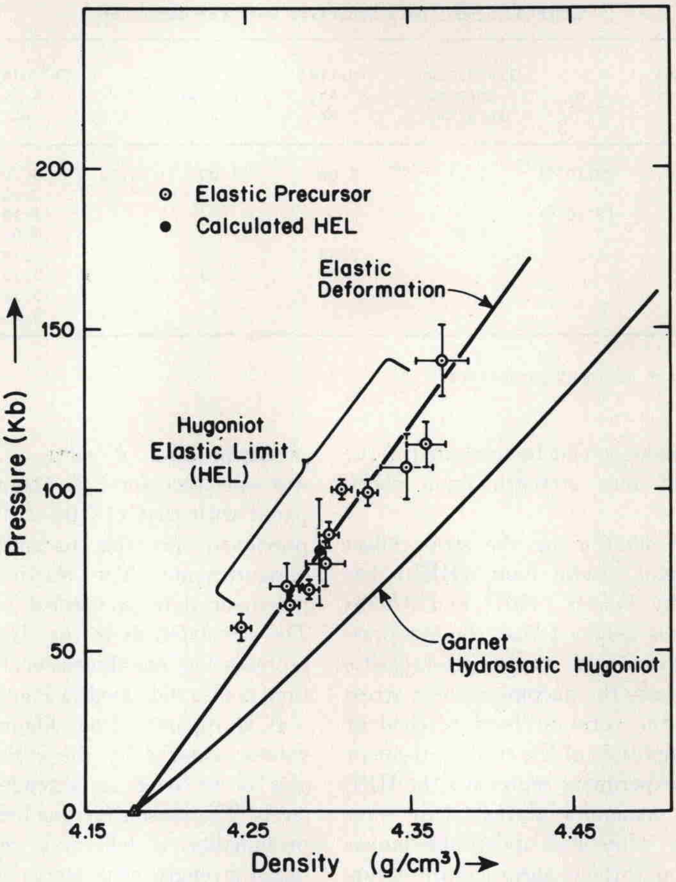

Fig. 7. Elastic precursor stress amplitudes for the Salida garnet. The offset of the HEL above the hydrostatic Hugoniot is 27 kb.

shear stress τ_{max} that our samples of Salida garnet withstood under a planar shock compression in the [100] direction is thus 20 ± 5 kb, according to the elastoplastic model.

It is clear from examining Figure 4 that subtracting 20 kb from the Hugoniot pressures of the three data points between 93 and 141 kb would destroy the apparently good agreement of the shock data with the X ray results. It is largely for this reason that we conclude that an elastoplastic model is not an appropriate rheological model for garnet when it is shocked substantially above its HEL. Although our limited data at low pressures are not conclusive, it appears that, in fact, garnet, like quartz [*Wackerle,* 1962], also behaves as a fluid above the HEL, and the corresponding Hugoniot curve lies close to the hydrostat.

CONCLUSIONS

The shock wave Hugoniot data for 18 samples of almandine-garnet covering a range in pressure from 100 to over 650 kb clearly indicate transformation to a high-pressure phase beginning at 195 ± 20 kb. Density requirements demanded by the high-pressure phase Hugoniot, in conjunction with crystal chemical arguments, strongly suggest that the high-pressure phase occurs in an ilmenitelike crystal structure. The density of the garnet hpp, based on crystal chemical systematics and supported by a tentative lattice parameter determination of shock-recovered material, is calculated to be 4.44 ± 0.04 g/cm³; this final value and probable error represent the weighted average of the various estimates. The material elastic properties for the high-pressure phase, calculated by using the