TABLE 1

THERMODYNAMIC PROPERTIES OF A CLASSICAL LJD FLUID UNDER SHOCK COMPRESSION, STARTING FROM THE LIQUID STATE AT $P^*=0$, $T^*=0\cdot 75$, $V^*=1\cdot 0503$

The symbols are defined in Section II

Pressure	P_1^*	0	3·007	22·32	123·7	371	1546
Volume	V_1^*	1·0503 (= V^*)	0·9899	0·8485	0·7071	0·6364	0·5657
Temperature	T_1^*	0·750	0·881†	1·605	7·202	26·31	144·9
Energy	E_1^*	−6·063	−5·972	−3·811	+15·16	+70·5	+368
Specific heat	$(C_V^*)_1$	2·577	2·653	2·710	2·724	2·499	2·248
Entropy	S_1^*‡	0	0·00	0·50	3·35	5·95	9·33
Shock velocity	U_1^*	6·47	7·41	11·04	19·94	31·44	59·3
Flow velocity	w_1^*	0	0·426	2·122	6·51	12·39	27·4
Velocity of sound	u_1^*	6·47	8·73	11·71	21·8	29·7	58·3

† All the temperatures to the right of this point are above the critical temperature for the liquid state ($T_c^*=1\cdot 3$).

‡ The listed values are relative to those at the starting point.

Secondly, there is a nearly linear relationship between the flow velocity and the shock velocity. This agrees with McQueen and Marsh's (1960) conclusions from measurements of these velocities in explosively shocked metals, and with Rice and Walsh's (1957) data for water.† The relationship would be exactly linear for very strong shock waves in a perfect gas.

Thirdly, the speed of sound u always exceeds the flow velocity w, which means that the flow is subsonic over the range of compressions considered. On the other hand, although the speed of sound is slightly greater than the shock velocity U at low pressures, it becomes less than U at high pressures. This is exactly the behaviour which Rice and Walsh (1957) have found in experiments on water and which McQueen and Marsh (1960) have observed in some shocked metals. In an ideal gas u may be either less or greater than w, and it is always less than U.

It seems from these comparisons that the LJD theory gives at least a qualitative description of the properties of shock waves in condensed materials. It is more difficult to test the theory quantitatively because of the paucity of good experimental data for liquids simple enough to conform to the LJD model. The theory assumes that the molecules of the material are non-polar and effectively spherical, and it is thus most appropriate to the condensed inert gases. Of these, only argon has been studied under shock conditions. Dapoigny, Kieffer, and Vodar (1955) have made a few X-ray determinations of the density of argon at shock pressures up to 72 000 atm. There are reasons for believing that their results may be suspect (Rice, McQueen, and Walsh 1958, p. 28) but in the absence of any other data it is worthwhile to compare them with the corresponding

† A plot of U against w from Rice and Walsh's data actually shows *two* straight lines, joined at about 120 000 atm. Altshuler, Bakanov, and Trunin (1958) believe that the discontinuity arises from the partial freezing of water at that pressure.

theoretical LJD Hugoniot curve. This comparison is made in Figure 2, where it will be seen that the agreement between the LJD curve and the experiments is not remarkably good : the LJD model consistently underestimates the specific volume. However, we should emphasize that our entire calculations involve only one experimental quantity, the second virial coefficient of gaseous argon used to derive the molecular units listed in Section II. The comparison in Figure 2 is therefore a very severe test of a long chain of reasoning linking the

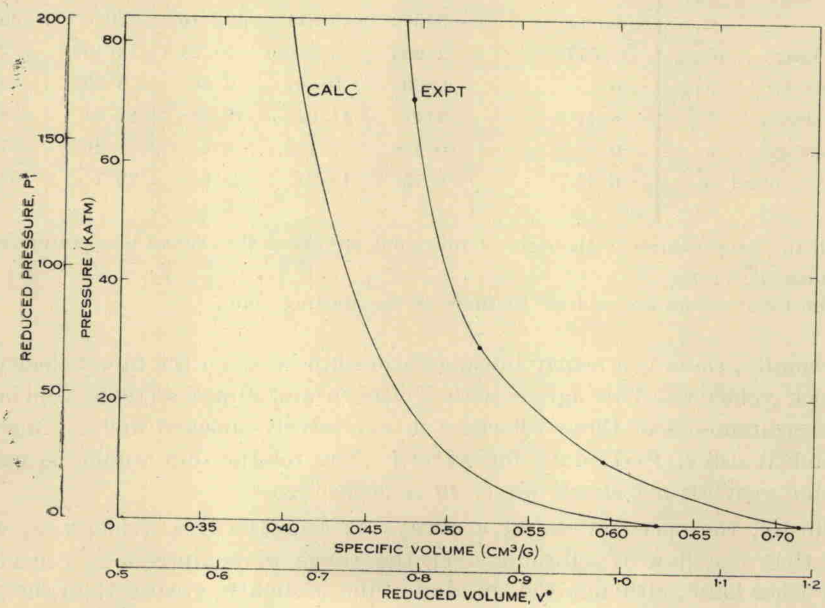

Fig. 2.—A comparison of the calculated LJD Hugoniot curve for liquid argon, initially at 1 atm and 87·2 °K ($P^* \approx 0$, $T^* = 0 \cdot 727$), with the experimental points of Dapoigny, Kieffer, and Vodar (1955). The calculated (LJD) temperature at the highest experimental point is 1230 °K.

properties of a highly compressed state with those of a dilute gas. We could undoubtedly improve the agreement by incorporating the experimental volume of liquid argon at $P \approx 0$, as was done by Fickett and Wood (1960). But this would be unrealistic, since at that volume the LJD theory predicts a metastable state with a negative pressure of about $P^* = -1 \cdot 7$. A more justifiable procedure is to calculate the ratio $\hat{V}_1/\hat{V}$ of the volume of the shocked fluid to that of the original liquid. If we do this we find that the LJD values of the ratio are very close to the experimental ones.

(*b*) *The Behaviour of a "Quantal" LJD Liquid*

The dotted curve in Figure 1 describes the Hugoniot compression of a quantal liquid ($\Lambda^* = 1$) calculated by the method outlined in Section III (*c*). It is displaced to volumes larger than those of the classical liquids.

Table 2 lists some thermodynamic properties of the fluid along the Hugoniot curve. Comparing these data with those in Table 1, we find that at any particular