

TABLE III

$v_0/v$	$E_C \cdot 10^{10}$ , erg/g	$P_C \cdot 10^{10}$ , bars	$P_H \cdot 10^{10}$ , bars
1.07	0.0525	0.132*	
1.15	0.181	0.200*	
1.19	0.30	0.332**	
1.25	0.585	0.463	0.484
1.30	0.86	0.600	0.645
1.35	1.18	0.761	0.840
1.40	1.57	0.942	1.07
1.45	1.97	1.154	1.36
1.50	2.42	1.358	1.67
1.55	2.94	1.613	2.08
1.60	3.51	1.880	2.55
1.65	4.12	2.174	3.13
1.70	4.79	2.484	3.82
1.75	5.54	2.822	4.66

\*From Ref. 8.

\*\*From Ref. 7.

sibility at high shock compression densities, where the dynamic adiabat differs considerably from the isotherm at absolute zero. Here and hereinafter, we shall not distinguish between isotherms at room temperature and at absolute zero.

We shall write the equation of state and an expression for the internal energy in the form

$$P = -\partial E_C / \partial v + BT/v; \quad (10)$$

$$E = E_C + C_V T. \quad (11)$$

Here  $-\partial E_C / \partial v = P_C$  is the compression pressure at  $T = 0^\circ K$ ,  $B$  is the thermal pressure coefficient,  $C_V$  is the specific heat at constant volume. In general,  $B$  and  $C_V$  can depend on temperature and density.

When temperature is eliminated we obtain the well-known caloric equation of state<sup>9-10</sup>

$$P + \frac{\partial E_C}{\partial v} = \gamma \frac{E - E_C}{v}. \quad (12)$$

The left member of (12) is the thermal component of the pressure and the ratio  $(E - E_C)/v$  in the right member is the volumetric density of thermal energy.

The Grüneisen coefficient  $\gamma = B/C_V$  gives the ratio of the thermal pressure to the thermal energy density. We shall consider this quantity to be a constant which like the unknown function  $E_C(v)$  must be obtained from experiment. For this purpose, substituting in (12) the expression for  $E$  given by the Hugoniot equation (2), we obtain the differential equation,

$$v \frac{\partial E_C}{\partial v} + \gamma E_C = -\gamma \frac{P_H(v)v}{2} \left(1 + \frac{2}{\gamma} - \frac{v_0}{v}\right). \quad (13)$$

When  $v_1 = v_0$ ,  $E_C = \partial E_C / \partial v = 0$ . In (13)  $P_H(v)$  is the experimental equation of the shock adiabat. The solution of (13) is given by

$$E_C = \frac{1}{(h-1)v^{2/(h-1)}} \int_{v_0}^v P_H(x) \left(\frac{v_0}{x} - h\right) x^{2/(h-1)} dx, \quad (14)$$

$$P_C = -\frac{\partial E_C}{\partial v} = \frac{2}{(h-1)^2 v^{(h+1)/(h-1)}} \quad (14a)$$

$$\times \int_{v_0}^v P_H(x) \left(\frac{v_0}{x} - h\right) x^{2/(h-1)} dx - \frac{1}{h-1} P_H(v) \left(\frac{v_0}{v} - h\right).$$

In (14)  $h = (2/\gamma) + 1$  is the so-called maximum density of shock compression.

At pressures from  $3 \times 10^5$  to  $5 \times 10^6$  atm,  $P_H(v)$  for iron is given by (9). We shall be committing only a very small error if, when calculating  $E_C$  in the region  $P > 3 \times 10^5$  kg/cm<sup>2</sup>, we consider (9) to apply also to the initial portion of the dynamic adiabat.

In order to determine  $\gamma$  and thus  $h$ , we shall compare two states 1 and 2 representing the shock compression of solid and of porous iron, respectively, to the same specific volume  $v_1$  (Fig. 1). Since both states have the same energy  $E_C$ , which depends only on the volume, the pressure difference  $\Delta P = P_2 - P_1 = \Delta P_T$  is accounted for by the thermal energy difference  $\Delta E = E_2 - E_1 = \Delta E_T$ . From (2)

$$\Delta E_T = \frac{1}{2} [P_2(v_{00} - v_1) - P_1(v_0 - v_1)]. \quad (15)$$

Here  $v_{00}$  is the initial volume of the porous iron and  $P_2$  is the shock compression pressure of the porous iron. The constants  $\gamma$  and  $h$  are obtained on the basis of (15) from the equations

$$\frac{1}{\gamma} = \frac{\Delta E_T}{v_1 \Delta P_T} = \frac{1}{2} \left[ \frac{v_{00} P_2 - v_0 P_1}{(P_2 - P_1) v_1} - 1 \right]; \quad (16)$$

$$h = \frac{(v_{00}/v_0) P_2 - P_1}{P_2 - P_1} \left( \frac{v_0}{v_1} \right). \quad (16a)$$

The available experimental data on the dynamic compressibility of porous iron (in Table II) permit us to obtain  $\gamma$  and  $h$  for two degrees of shock compression. The values of these parameters are given in the last two columns of Table II. For the transition from the dynamic adiabat to the isotherm  $T = 0$ ,  $h$  is more important at high compressions, that is, in the region where the thermal components of the pressures are relatively large. In subsequent calculations, we shall assume  $h = 2.25$ .

The values of the cold compression energy  $E_C$  and of the pressure  $P_C = -\partial E_C / \partial v$  calculated from (14) are given in Table III for pressures from 0.3 to 5 million atmospheres. Also given are the pressures  $P_H(v_0/v)$  of the shock adiabat for the compression of iron of normal density, which were calculated from the interpolation formula (9).

Knowing the function  $E_C$  and its derivative, we