TABLE III. Shock wave data for carbon tetrachloride.

Initial density (g/cc)	Shock velocity (km/sec)	Particle velocity (km/sec)	Pressure (kbar)	Relative volume (V/V_0)	Dural shock velocity (km/sec)
1.590	2.32±0.01	0.72±0.08	27±3	0.688±0.035	5.93±0.07
1.577	2.27±0.01	0.84±0.04	30±2	0.631±0.018	6.02±0.03
1.571	2.47±0.01	0.83±0.04	32±2	0.663±0.018	6.02±0.04
1.571	2.79±0.01	0.97±0.03	43±1	0.652±0.010	6.16±0.02
1.586	2.91±0.01	1.03±0.03	48±1	0.645±0.010	6.22±0.03
1.594	2.95±0.01	1.04±0.04	49±2	0.648±0.012	6.23±0.03
1.596	3.28±0.01	1.25±0.03	65±1	0.619±0.008	6.43±0.02
1.571	3.32±0.01	1.33±0.02	70±1	0.598±0.006	6.50±0.02
1.606	3.46±0.01	1.33±0.02	74±1	0.615±0.007	6.52±0.02
1.591	3.44±0.01	1.36±0.02	74±1	0.606±0.007	6.54±0.02
1.598	3.50±0.01	1.45±0.08	81±5	0.585±0.023	6.62±0.07
1.577	3.74±0.01	1.61±0.02	95±1	0.568±0.006	6.78±0.02
1.571	3.86±0.01	1.69±0.01	102±1	0.563±0.003	6.86±0.01
1.606	4.08±0.01	1.73±0.04	113±3	0.576±0.011	6.92±0.04
1.580	4.07±0.01	1.77±0.02	114±1	0.566±0.005	6.95±0.02
1.571	4.27±0.03	1.97±0.09	132±6	0.539±0.021	7.14±0.08
1.571	4.52±0.01	2.07±0.02	148±1	0.542±0.003	7.26±0.01
1.586	4.66±0.01	2.10±0.02	156±1	0.549±0.004	7.31±0.02
1.596	4.71±0.01	2.15±0.04	161±3	0.544±0.008	7.35±0.03
1.574	4.88±0.01	2.36±0.03	182±2	0.516±0.006	7.56±0.03
1.610	5.34±0.02	2.55±0.03	220±2	0.522±0.005	7.80±0.03
1.580	5.21±0.01	2.62±0.02	216±2	0.497±0.004	7.83±0.02
1.588	5.72±0.03	2.95±0.07	268±7	0.484±0.013	8.20±0.06
1.571	5.69±0.02	3.06±0.05	274±5	0.461±0.009	8.29±0.05
1.571	6.13±0.03	3.22±0.03	311±3	0.476±0.005	8.48±0.03
1.584	6.44±0.05	3.44±0.08	352±9	0.465±0.014	8.74±0.08
1.598	6.80±0.02	3.64±0.04	395±4	0.466±0.006	8.97±0.04
1.582	6.72±0.02	3.69±0.07	392±7	0.451±0.010	9.00±0.06
1.580	6.78±0.03	3.77±0.08	404±9	0.444±0.013	9.08±0.08
1.586	7.13±0.03	4.05±0.06	458±7	0.432±0.008	9.39±0.05
1.588	7.55±0.02	4.40±0.06	527±7	0.417±0.008	9.77±0.06
1.588	7.96±0.03	4.58±0.06	579±8	0.425±0.009	10.00±0.06
1.598	8.06±0.06	4.74±0.13	611±17	0.411±0.017	10.17±0.12
1.580	8.24±0.04	4.74±0.11	617±14	0.425±0.014	10.18±0.10
1.584	8.26±0.03	4.84±0.10	633±13	0.415±0.012	10.28±0.09

velocity and the excellent agreement between the measured sound speed[19] and the intercept of the lower line with the U_s axis. The line segments were determined by a least-squares fit of the $U_s - U_p$ data; in the region $2.40 \leq U_s \leq 3.50$ km/sec the relationship is

$$U_s = 1.18 \pm 0.22 + (1.67 \pm 0.14) U_p, \qquad (9)$$

and from $3.50 \leq U_s \leq 8.20$ km/sec,

$$U_s = 1.11 \pm 0.07 + (1.35 \pm 0.02) U_p. \qquad (10)$$

In the particle velocity interval of 1.39 to 1.84 km/sec, the shock velocity is essentially constant. The data of Walsh and Rice[8] agree with the present data but those of Cook and Rogers[9] do not. The abrupt change in the slope and the offset of the two line segments indicates a transition occurring at about 62 kbar ($U_s = 3.50$ km/sec, $U_p = 1.40$ km/sec, and $\rho_0 = 1.263$ g/cc) with a new phase formed at about 80 kbar ($U_s = 3.50$ km/sec, $U_p = 1.80$ km/sec, $\rho_0 = 1.263$ g/cc). The intercept of the lower line segment with the U_s axis (1.18 km/sec) is very close to the measured sound speed of 1.16 km/sec, indicating that carbon disulfide is in the liquid state from 1 bar–62 kbar.

The $P - V/V_0$ plot of Fig. 7 is characterized by concave upward curves above 80 kbar and below 62 kbar with a well-defined cusp representing the transition at 62 kbar. A straight line segment joins the two major curves. Using the lower curve as a reference, the decrease in relative volume ascribed to the transition is nearly 17%. Every point on the $P - V/V_0$ curves can be reached by the Rayleigh line in a single shock originating from the P_0, V_0 point. As a result there is no double shock wave structure associated with the transition even though an interval of constant shock velocity was observed in the $U_s - U_p$ plot. This was confirmed by experiment (see Sec. II). The

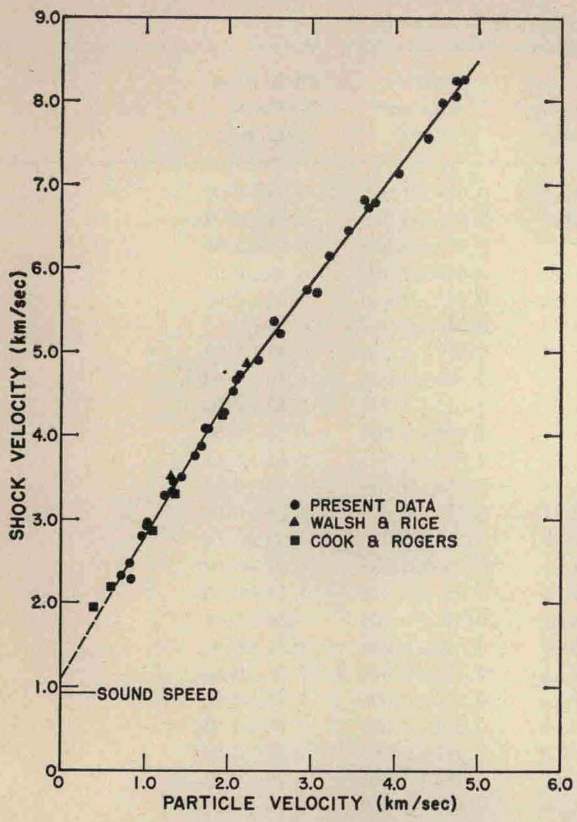


FIG. 8. Shock velocity-versus-particle velocity plot for carbon tetrachloride.

similarity in the observed behavior between carbon disulfide and benzene indicates that carbon disulfide undergoes an instantaneous transformation to a mixed phase material at 62 kbar with the new phase being completely formed at 80 kbar. In addition, the shock wave remains stable at and above the transition pressure.

The observed transition is thought to be a transformation from the liquid state to a "black substance" as observed by Bridgman.[4] Whalley[23] and Butcher *et al.*[24] investigated the phenomenon and the transformed material in more detail. They found that under static pressures the transition takes place at about 40 kbar over a temperature range of 120–200°C. The black substance was determined to be an amorphous form of carbon disulfide, stable at ambient pressure and temperature, and has some of the characteristics of a semiconductor. In some experiments[25] where carbon disulfide was shocked to about 200 kbar, a black fluffy solid was recovered which may be the solid observed in the static experiments.

Some experiments were performed to determine the electrical properties of carbon disulfide near the transition pressure. It was observed, with rather insensitive instrumentation, that there was negligible electrical conductivity below the transition pressure. However, near 80 kbar the conductivity increased significantly, indicating a connection between the transition and electrical conduction.

D. Carbon Tetrachloride

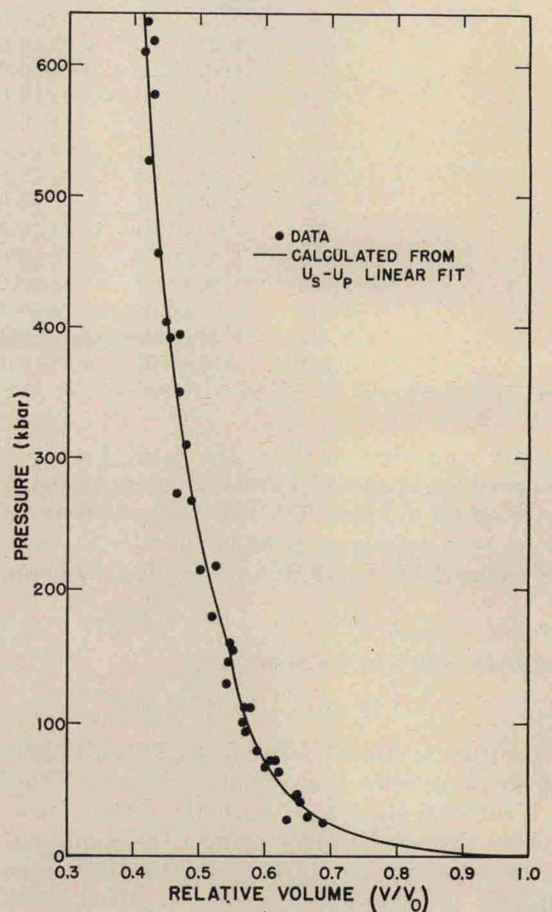
Carbon tetrachloride, in some respects, has a less complicated behavior under shock conditions than either benzene or carbon disulfide. In Table III are the Hugoniot data obtained from the experiments. The U_s-U_p data are plotted in Fig. 8 and are fit by two straight lines. They differ in slope, but there is no displacement of the two segments. The lines are fitted by

$$U_s=1.11\pm0.08+(1.67\pm0.05)U_p \qquad (11)$$

in the range $2.30\leq U_s\leq 4.70$ km/sec. Above $U_s=4.70$ km/sec the linear relationship is

$$U_s=1.87\pm0.14+(1.32\pm0.03)U_p. \qquad (12)$$

These lines intersect at $U_s=4.70$ and $U_p=2.17$ km/sec. A least-squares fit of the data to a quadratic in the particle velocity resulted is a smooth curve through



. Pressure-versus-relative volume plot for carbon tetrachloride.