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Shock Wave Compression of Benzene, Carbon Disulfide, Carbon Tetrachloride, and Liquid Nitrogen*,†

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Hugoniot data to several hundred kilobar have been obtained for benzene, carbon disulfide, carbon tetrachloride, and liquid nitrogen. Standard high explosive techniques were used for generating the shock waves. Experimentally measured quantities were transformed to pressure and volume data by the impedance match method. The shock-particle velocity data for the liquids are described by a linear relationship, however, a quadratic in particle velocity also provides an adequate representation of the data for carbon tetrachloride and liquid nitrogen. Benzene undergoes a transition at 133 kbar and carbon disulfide at 62 kbar. These transitions are accompanied by a volume decrease of approximately 16%. A double shock-wave structure, observed in many solids which undergo a transition, was not observed in benzene and carbon disulfide. There is some evidence that carbon tetrachloride and liquid nitrogen undergo a transition at 165 and 135 kbar, respectively. Hugoniot curves calculated from a Lennard-Jones and Devonshire (6-9) and a modified Buckingham exp-6 intermolecular potential fit the liquid nitrogen experimental Hugoniot curve between 20 and 170 kbar.

I. INTRODUCTION

These are the results of an investigation to determine some of the properties of benzene, carbon disulfide, carbon tetrachloride, and liquid nitrogen when shocked to pressures of several hundred kilobars. The pressures were produced by plane shock waves, created by detonating high explosives. The initial temperature of the three organic liquids was approximately 295°K and of the liquid nitrogen 75°K.

There is very little high-pressure data available on these liquids. Bridgman[1–7] has obtained most of the static pressure data. A limited amount of shock compression data were obtained by Walsh and Rice[8] for benzene, carbon disulfide, and carbon tetrachloride, using optical techniques. More extensive dynamic data for these liquids were collected by Cook and Rogers,[9] also using optical methods. Zubarev and Telegin[10] obtained some Hugoniot data for liquid nitrogen using techniques similar to those of this investigation.

The "impedance match method" was used to transform the measured shock velocities to pressure, particle velocity, and relative volume data. These data are presented in shock velocity-versus-particle velocity and pressure-versus-relative volume plots. In addition some rough electrical conductivity experiments were carried out on benzene, carbon disulfide, and carbon tetrachloride. The discovery that benzene and carbon disulfide undergo a transition prompted experiments to detect the presence of a double shock-wave structure associated with the transition; the results were negative.

II. EXPERIMENTAL TECHNIQUE

The impedance match method, as used in this study, requires the measurement of the shock velocity and the initial density of the material being examined and the shock velocity in a standard to determine the Hugoniot data. In this investigation 2024 dural was used as the standard. The Rankine–Hugoniot relations[11–13]

$$P-P_0=\rho_0 U_s U_p, \tag{1}$$

$$V/V_0=(U_s-U_p)/U_s, \tag{2}$$

for conservation of momentum and mass across the shock front provide the connection between the measured quantities and the Hugoniot point for the unknown material. The pressure and particle velocity

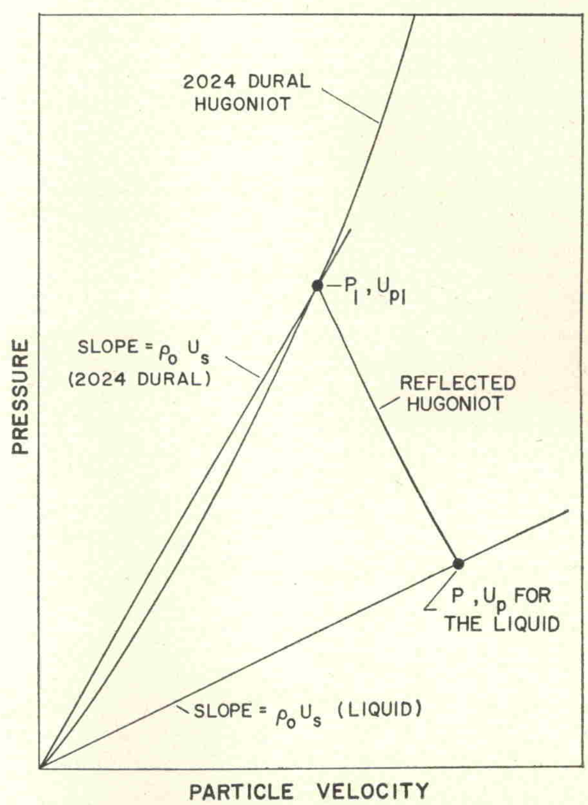

FIG. 1. Graphic representation of the impedance match method.

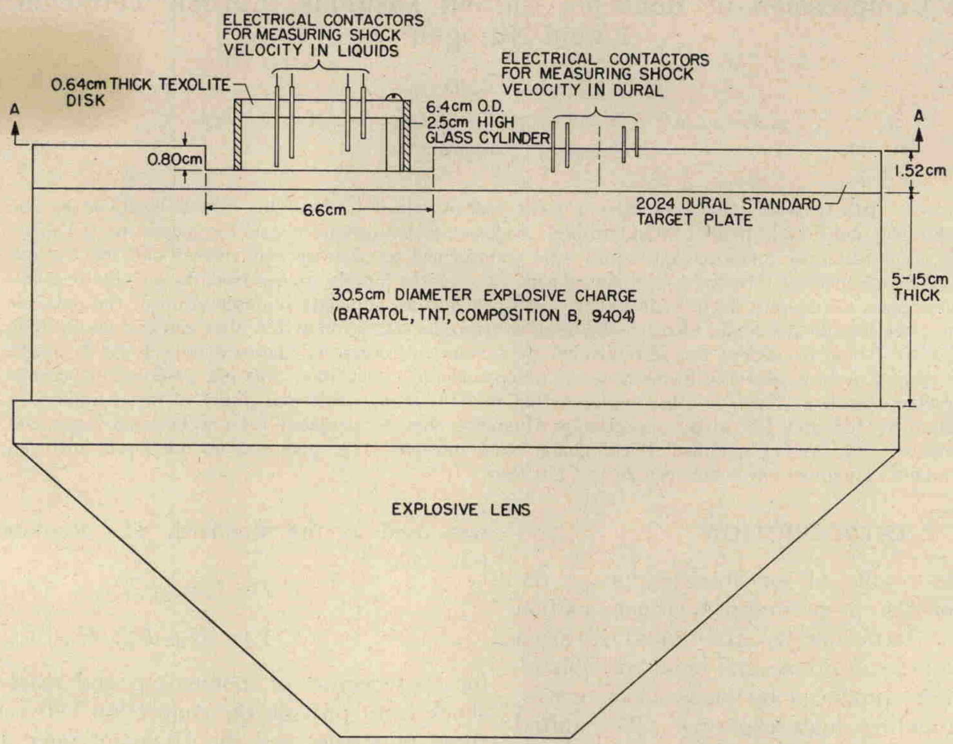

FIG. 2. Cross-sectional view of the shot assembly used for the organic liquids.

must be continuous across the interface between the standard and the material under study. In the above equations P_0 and $V_0(=1/\rho_0)$ represent the pressure and specific volume ahead of the shock front and P and V the pressure and specific volume behind the shock front. U_s and U_p represent the shock velocity and particle velocity relative to the undisturbed material ahead of the shock front. V/V_0 is defined as the relative volume. The curves in the $P-U_p$ plane in Fig. 1 illustrate the impedance match method. The measurement of the shock velocity in the known 2024 dural determines the state P_1, U_{p1}. From this point the reflected Hugoniot curve is constructed and intersects the line of slope $\rho_0 U_s$ determined for the liquid. This intersection is the pressure and particle velocity (P, U_p) in the sample.

The Hugoniot for the 2024 dural has been measured very accurately at ambient temperature. The equation of state[14] is expressed by

$$U_s = 5.328 + 1.338 U_p, \tag{3}$$

with $\rho_0 = 2.785$ g/cc and the Gruneisen ratio $\Gamma_0 = 2.0$.

A detailed description of the experimental apparatus and fabricating techniques are given in Ref. 15. A cross-sectional view of the experimental apparatus used for the organic liquids is presented in Fig. 2. Three liquids were examined in a single experiment. Each liquid was contained in a glass cylinder set into a well machined in the target plate. The shock ve-

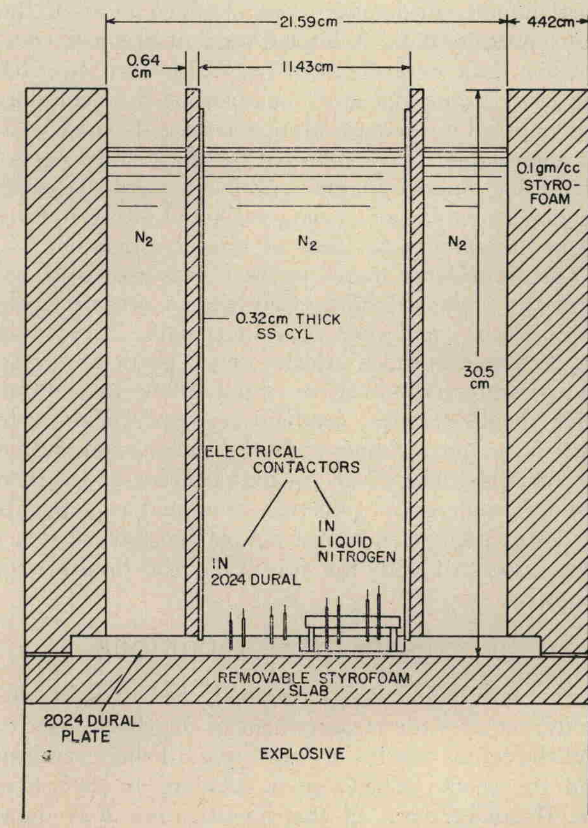

FIG. 3. Cross section view of the apparatus used for the liquid nitrogen.