Measurement of Chapman-Jouguet Pressure for Explosives*

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The Chapman-Jouguet pressures of RDX, TNT, 64/36 Composition B, and 77/23 Cyclotol have been measured by determining initial free-surface velocity as a function of thickness for 24ST aluminum plates in contact with the detonating explosive. An optical technique is described for the measurement of the velocities. The pressures determined for RDX, TNT, 64/36 Composition B, and 77/23 Cyclotol are 338, 189, 292, and 313 kilobars, respectively.

INTRODUCTION

It was first suggested by Goranson[1] in 1945 that explosive pressures could be established by measurement of the free-surface velocity as a function of thickness for metal plates in contact with the explosive. Duff and Houston[2] reported measurements of this type for Composition B made by an electrical contactor method. This paper will present similar measurements made for RDX, TNT, Composition B, and Cyclotol by an optical technique.

BASIC PRINCIPLES

A steady-state plane detonation wave has been described by Zeldovich,[3] von Neumann,[4] and Döring[5] as a shock followed by a reaction zone of decreasing pressure terminating at the Chapman-Jouguet (C-J) plane. The unsteady flow behind this plane of complete reaction has been described by Taylor[6]; such flow is essentially a rarefaction wave centered at the rear of the explosive. The generally accepted picture of the pressure profile of a detonation wave is thus much like that of Fig. 1.

When such a wave impinges upon an inert material in contact with the explosive, the wave transmitted is a shock followed closely by a steep rarefaction which is in turn followed by a more gradual rarefaction. The shock impedance discontinuity at the interface also causes disturbances (shocks or rarefactions depending on the direction of change of impedance) to be reflected back into the explosive. The effect of this reflected wave on the reaction kinetics and any consequent change in the C-J state is assumed to be negligible in the following discussion. As the transmitted wave travels through the inert material, the steep rarefaction overtakes and eliminates that portion of the wave corresponding to the von Neumann pressure spike. Then in further travel through the material, the rarefaction corresponding to the Taylor wave more gradually overtakes and reduces the pressure of the remaining shock front. Shock front pressure in the inert as a function of the thickness of that material thus varies qualitatively as shown in Fig. 2. Each point of this pressure-thickness curve may be considered as related to a point on the pressure profile of the detonation wave. P_m^*, in particular, corresponds to the pressure at the C-J plane in the detonation wave.

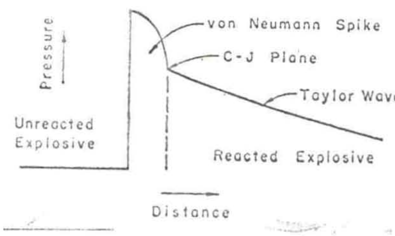

FIG. 1. Generally accepted picture of the pressure profile of a detonation wave.

If one considers the interaction at the explosive-inert material interface as shown in Fig. 3, one can write

$$P_m = P_x + \rho_r^0 D_r (U_x - U_m), \qquad (1)$$

where P_x is the pressure in the detonation wave, P_m is the induced pressure in the inert material, and the ρ's, U's, and D's are densities, particle velocities, and shock (or detonation) velocities, respectively, particularized by the subscripts: x referring to the detonation wave, m referring to the inert material, and r referring to the reflected wave in the explosive. Conditions in front of these waves are referred to by a superscript zero. All velocities are measured relative to the particle velocities in front of the wave. Then using the momentum conservation equations, $P_x = \rho_x^0 U_x D_x$ and $P_m = \rho_m^0 U_m D_m$,

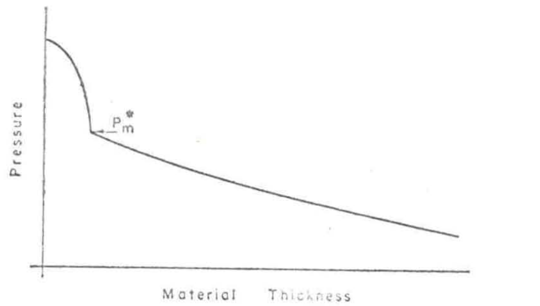

FIG. 2. Shock front pressure as a function of material thickness (qualitative). P_m^* is the inert material pressure corresponding to C-J pressure in the explosive.

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[1] R. W. Goranson, Classified Los Alamos Report LA-487.

[2] R. E. Duff and E. Houston, J. Chem. Phys. 23, 1268 (1955).

[3] Y. B. Zeldovich, J. Exptl. Theoret. Phys. (U.S.S.R.) 10, 542 (1940).

[4] J. von Neumann, OSRD Report No. 549 (1942).

[5] W. Döring, Ann. Physik 43, 421 (1943).

[6] G. I. Taylor, Proc. Roy. Soc. (London) A200, 235 (1950).