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INFORMAL REPORT

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Decay of Overdriven Detonations in Nitromethane

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W. Fickett

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ABSTRACT

The decay rates of overdriven detonations initiated by Composition B and PBX9404 are calculated. These calculations were requested in connection with a proposal to use the measured rate of luminosity decay of an overdriven nitromethane detonation to obtain a qualitative picture of the profile of the initiating wave.

I. INTRODUCTION

An experimental method is being developed for inferring the pressure profile near the front in a shock or detonation wave by observing the decay of light intensity in an overdriven nitromethane detonation initiated by the shock or detonation in question.

As part of this effort, we have calculated two examples, using the one-dimensional characteristics code RICSHAW. An instananeous-reaction unsupported CJ detonation in a unit length of PBX9404 or Composition B initiates the overdriven detonation in a semi-infinite slab of nitromethane, Fig. 1. The nitromethane is also assumed to have instantaneous reaction so that the initial match is to its complete-reaction Hugoniot.

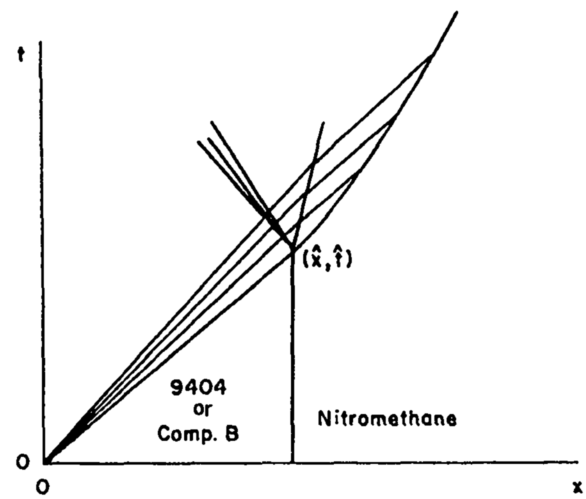

Fig. 1. Overdriven detonation in nitromethane initiated by PBX9404; x-t diagram.

II. RESULTS

The results are given in Table I and Figs. 2 and 3. In the RICSHAW characteristic diagrams, Figs. 2a and 3a, the initiation point for the driver explosive is at $x = 11$, and the interface between the two explosives is at $x = 10$. The variable x in the remaining figures is in the coordinate system of Fig. 1.

Analytic results for a similar problem suggest a certain presentation of the results. In a material obeying the Walsh EOS (Hugoniot $U = a + bu$ and the same p-u locus for the rarefaction) let an initially flat-topped shock be overtaken at $\hat{x}$, $\hat{t}$ by the head of a rarefaction wave centered at $x = t = 0$. The subsequent shock trajectory is given by (exactly):

$$y - a = (\hat{y} - a)(t/\hat{t})^{-1/2} \quad ; \quad y \equiv x/t \ . \qquad (1)$$

TABLE I

DECAY OF OVERDRIVEN DETONATION IN NITROMETHANE

Explosives (γ-law equation of state)

	ρ_o	D_j	P_j	γ_j
Nitromethane	1.13	0.6250	141	2.13
PBX9404	1.84	0.8800	356	3.00
Composition B	1.714	0.7991	290	2.769

Nitromethane Front States, Composition B Driver

T	X	P	U	1/SQRT(T)	Y=X/T	Y-YCALC
1.25141	1.00000	.20816	.27896	.89392	.79910	-.00000
1.40340	1.10000	.20201	.27268	.84413	.78381	-.00559
1.55639	1.20000	.19672	.26715	.80157	.77101	-.01010
1.71023	1.30000	.19232	.26245	.76467	.76013	-.01379
1.86475	1.40000	.18859	.25840	.73230	.75077	-.01685
2.01984	1.50000	.18534	.25482	.70363	.74263	-.01940
2.17543	1.60000	.18247	.25161	.67800	.73549	-.02156
2.33144	1.70000	.18002	.24884	.65492	.72916	-.02339
2.48781	1.80000	.17783	.24634	.63400	.72353	-.02495
2.64449	1.90000	.17586	.24407	.61493	.71848	-.02629
2.80145	2.00000	.17408	.24200	.59746	.71392	-.02744
∞	∞	.14102	.19968	0.00000	.62500	0.00000

Nitromethane Front States, PBX9404 Driver

T	X	P	U	1/SQRT(T)	Y-X/T	Y-YCALC
1.13636	1.00000	.23527	.30523	.93808	.88000	.00000
1.28375	1.10000	.22644	.29694	.88259	.85686	-.00805
1.43261	1.20000	.21878	.28956	.83548	.83763	-.01448
1.58275	1.30000	.21230	.28316	.79487	.82136	-.01971
1.73393	1.40000	.20704	.27785	.75942	.80741	-.02402
1.88598	1.50000	.20244	.27313	.72817	.79534	-.02760
2.03880	1.60000	.19839	.26891	.70035	.78478	-.03060
2.19227	1.70000	.19481	.26511	.67539	.77545	-.03314
2.34632	1.80000	.19167	.26175	.65284	.76716	-.03530
2.50086	1.90000	.18895	.25879	.63235	.75974	-.03715
2.65583	2.00000	.18649	.25609	.61362	.75306	-.03874
∞	∞	.14102	.19968	0.00000	.62500	0.00000

We guess that an analogous equation might describe fairly well the decay of the overdriven detonation in nitromethane:

$$y - D_j = (\hat{y} - D_j)(\hat{t}/t)^{-1/2} \quad , \qquad (2)$$

where we have replaced the sound speed a of Eq. (1), to which the shock velocity finally decays, by the nitromethane Chapman-Jouguet detonation velocity D_j, to which the detonation velocity finally decays. Here, of course, $y = x/t$ is the trajectory of the detonation front.

In Figs. 2b, 2c and 3b, 3c we have plotted y and p from the RICSHAW calculations vs. $t^{-1/2}$, as suggested by Eq. (2). The curves are not as linear as we had hoped, but should still be useful for extrapolation to later times. In Figs. 2d and 3d we show the difference between the RICSHAW y and that from Eq. (2) ("Y CALC"), to display the non-linearity in more detail.

The magnification ratio, illustrated in Fig. 2a, is the ratio of the length of run of the detonation front in nitromethane to the length of the portion of the profile in the driver explosive which influences it. For example, in Composition B, Fig. 2a, if we measure the nitromethane detonation front history over a travel of 1.1 cm, we can infer (approximately) only the front 1.1/13 = 0.85 cm of the Composition B pressure profile.

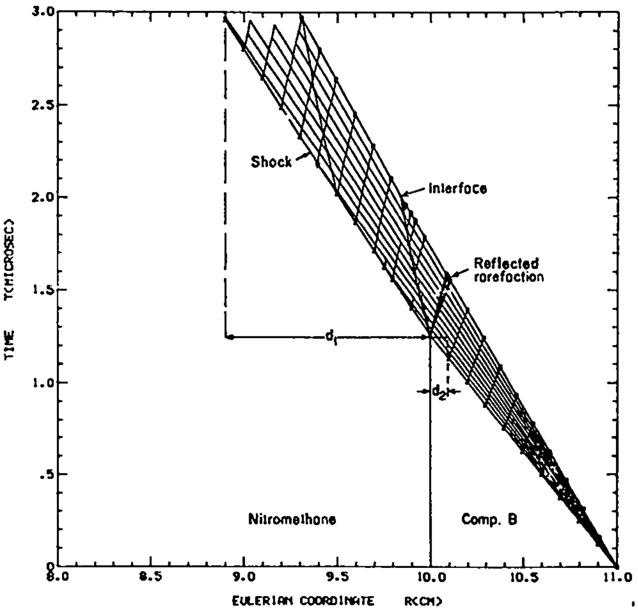

Fig. 2a.

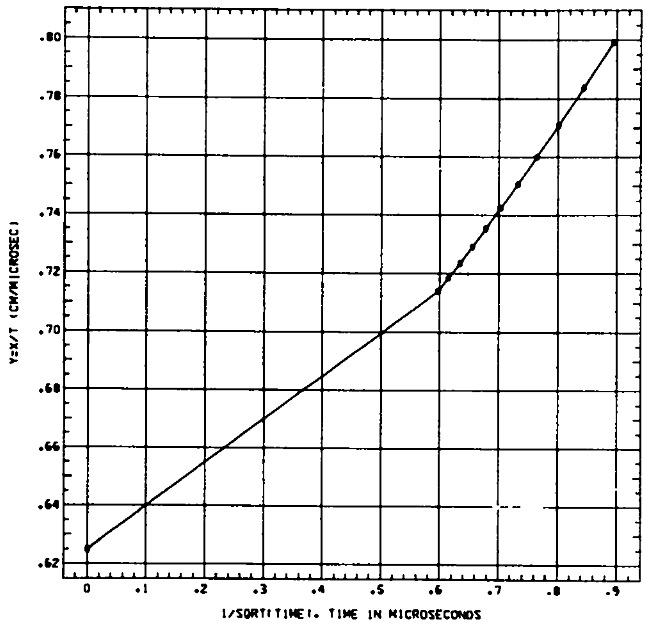

Fig. 2b.

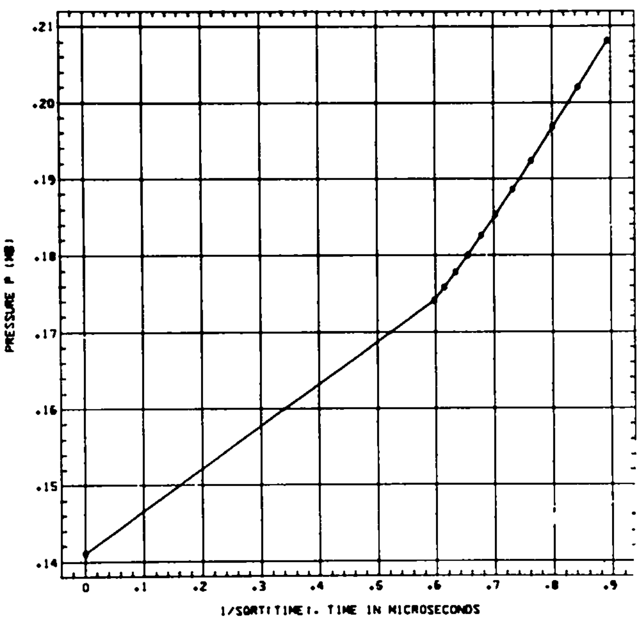

Fig. 2c.

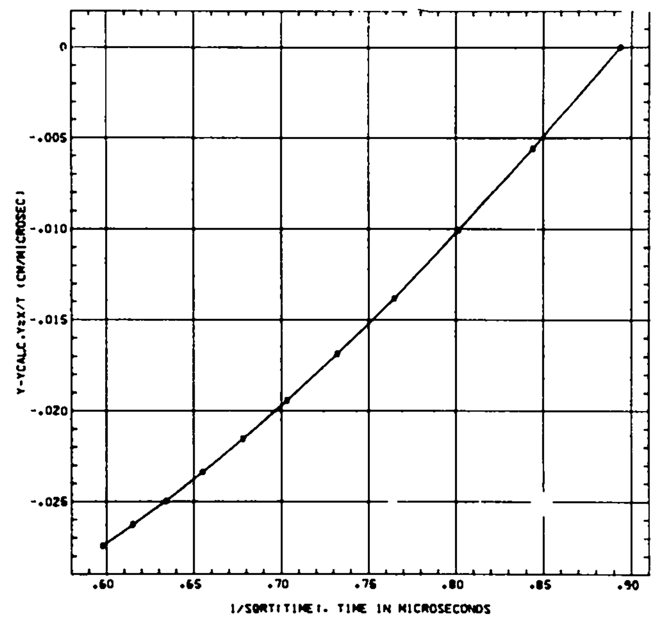

Fig. 2d.

Fig. 2. Composition B/nitromethane

a. Characteristic diagram. The magnification ratio is $d_1/d_2 = 13$.

b. y vs. $t^{-1/2}$, see text

c. p vs. $t^{-1/2}$

d. Difference between RICSHAW y and that calculated from Eq. (2) vs. $t^{-1/2}$

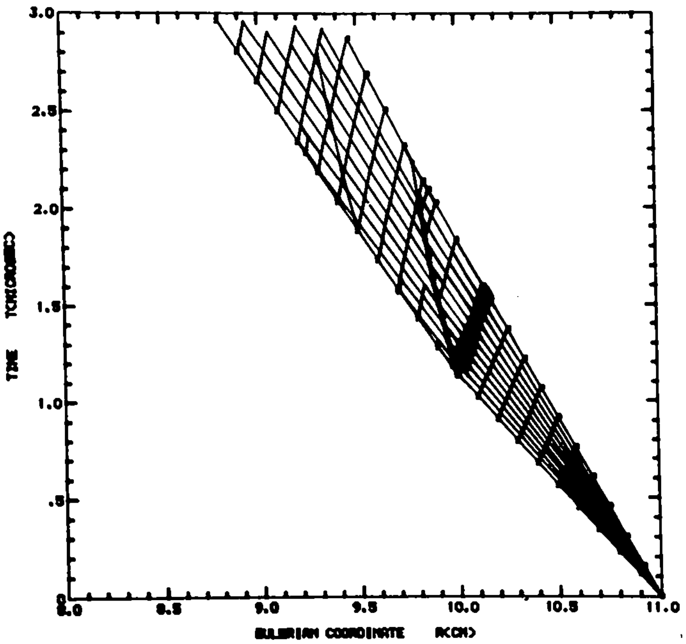

Fig. 3a.

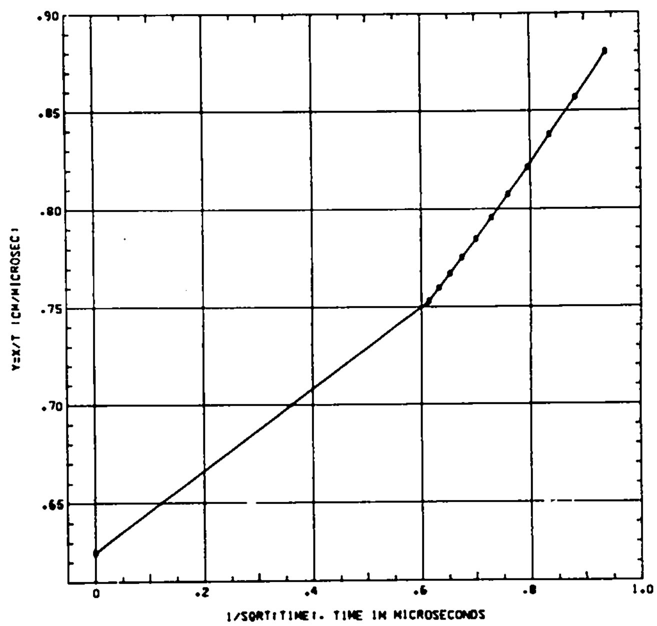

Fig. 3b.

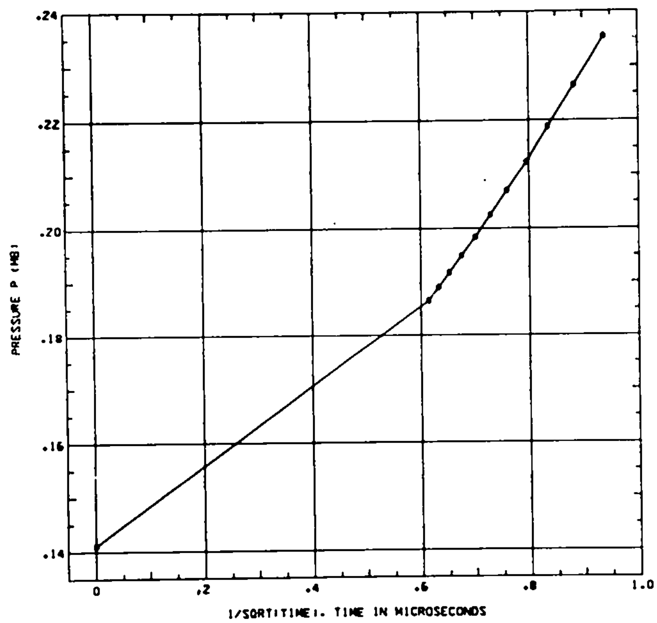

Fig. 3c.

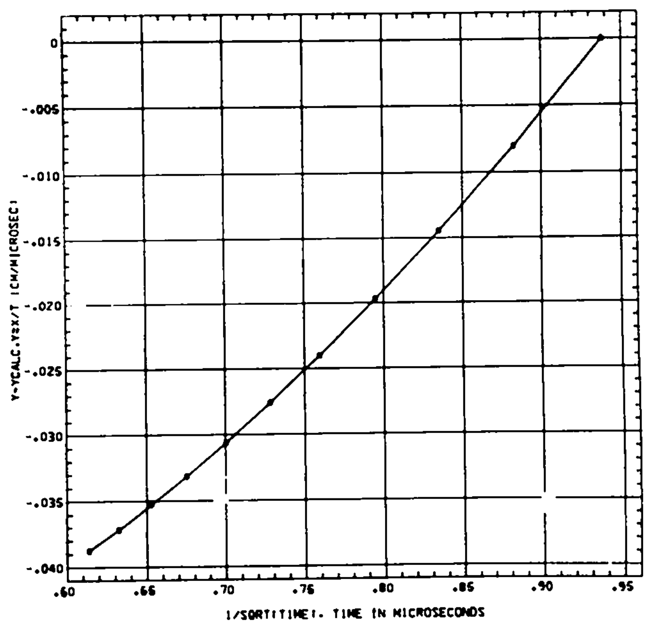

Fig. 3d.

Fig. 3. PBX9404/nitromethane, same as Fig. 2. The magnification ratio is 9.