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AUTHOR(S): Robert H. Dinegar

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Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

THE RADIAL BUILDUP TO DETONATION IN PENTAERYTHRITOL TETRANITRATE (PETN)

Robert H. Dinegar
Los Alamos National Laboratory

. INTRODUCTION

The majority of explosive compounds can be classified (informally at least) with respect to the process by which a self-sustaining steady-state detonation is reached. Those initiated explosives that appear to achieve detonation directly, i.e., without a significant burning zone, are generally listed as primary explosives. Well-known examples are the majority of azide salts, (lithium, lead, calcium, thallous, and silver azide) plus several fulminate compounds, viz. the silver, thallous, cadmium, and cuprous salts. In these compounds a build-up burning stage appears to be absent and a low order (~2000 m/s) detonation begins close to the point of initiation.

On the other hand, there are a large number of initiated explosives that clearly show a burning zone preceeding the stable detonation. The compounds that exhibit a smooth transition from an accelerative deflagration into a self-sustaining steady detonation are called secondary explosives. Familar examples of this class are pentaerythritol tetranitrate (PETN), N-methyl-N, 2, 4, 6-tetranitrobenzenamine (Tetryl), hexahydro-1, 3, 5-trinitro-1, 3, 5 triazine (RDX), and octahydro-1, 3, 5, 7-tetranitro-1, 3, 5, 7-tetrazocine (HMX).

The reason for the absence or presence of an apparent burning region has been the subject of much discussion over the years. An acceptable simple suggested explanation is that, in the first case, the decomposition reaction liberates heat sufficient in quantity and rate of evolution to give rise almost immediately to the end condition, i.e., a self-sustaining stable detonation. Presumably then, the appearance of a burning zone indicates a less rapid generation or smaller amount (or both) of heat. In short, the balance between the productive and dissipative heat processes determine whether a burning zone is operative or not.

This paper deals with a study made on the initiation of the very common and available secondary explosive PETN. In it we report the radial velocities involved in the buildup from deflagration to detonation.

II. EXPERIMENTAL PROCEDURE

Purified PETN was pressed to a density of 0.95 g/cc in Lucite cylinders of 2.54-cm diameter and 0.76-cm length. These charges were initiated by means of an exploding bridgewire located in the center of one face of the pressing. The firing capacitance and inductance were held constant. The energy delivered to the explosive charge was changed by varying the condenser voltage. The radial buildup to detonation was recorded by a rotating mirror camera with the slit perpendicular to the bridgewire.

III. EXPERIMENTAL RESULTS

The firing voltage at which 50% of the PETN charges detonate (called the "threshold") is slightly above 1000 V for these pressings. Let us look, in some detail, at the detonation buildup phenomenon as increasing amounts of energy are delivered to the PETN by a variation in the condenser voltage from 1000 V to 4000 V.

At 1000 V the PETN charge fails to achieve steady-state detonation, Fig. 1 shows clearly that reaction starts but soon dies out. In fact, the assembly was recovered with only a small fraction of the PETN decomposed. The velocity of the decomposition as a function of the radial distance from the bridgewire is shown in Fig. 2. The rates go through a maximum close to the region of ignition and then decelerate, eventually dying out. The magnitude of the velocities involved are a factor of ten less than those of detonating explosives; they are characteristic of deflagration reactions.

The first appearance of initiation leading to detonation occurs about 1050 V. Under these minimal firing conditions, the initiation is asymmetrical around the center of the bursting bridgewire. Fig. 3 clearly shows the right hand side of the assembly detonating before the PETN on the left. The difference in time of appearance of explosion light on the two sides, relative to the bursting bridgewire light, is 0.28 μs..

Figure 3 shows the initiation at higher voltages. It is apparent that 1) the initiation is symmetrical with respect to the bursting bridgewire region, and 2) the detonation traces occur closer to the bursting bridgewire light as the voltage increases. Using the first burst of bridgewire light as a point of reference, the time delay before the onset of detonation may be found. This is shown as a function of firing voltage in Table 1. The data indicate that condenser energies of 4.5 J (V = 3000) or more dis-

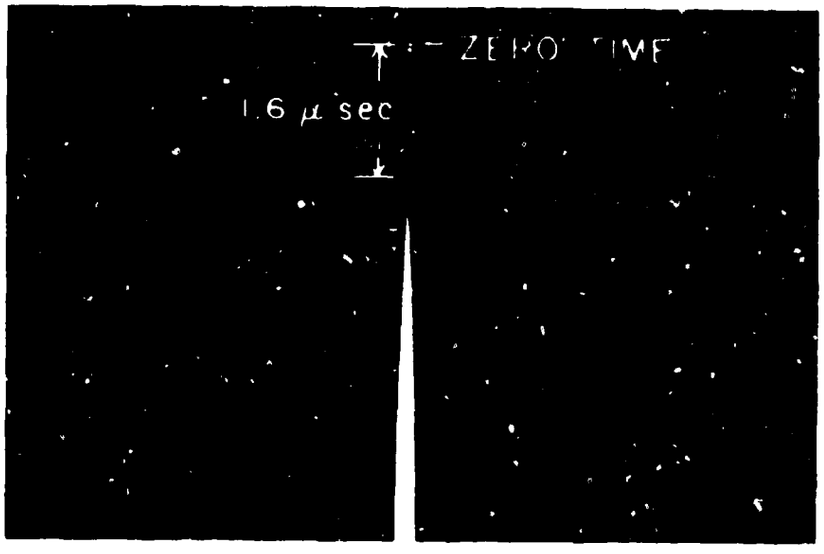

Fig. 1

Failure of PETN charge to detonate
Firing Voltage = 1000 V

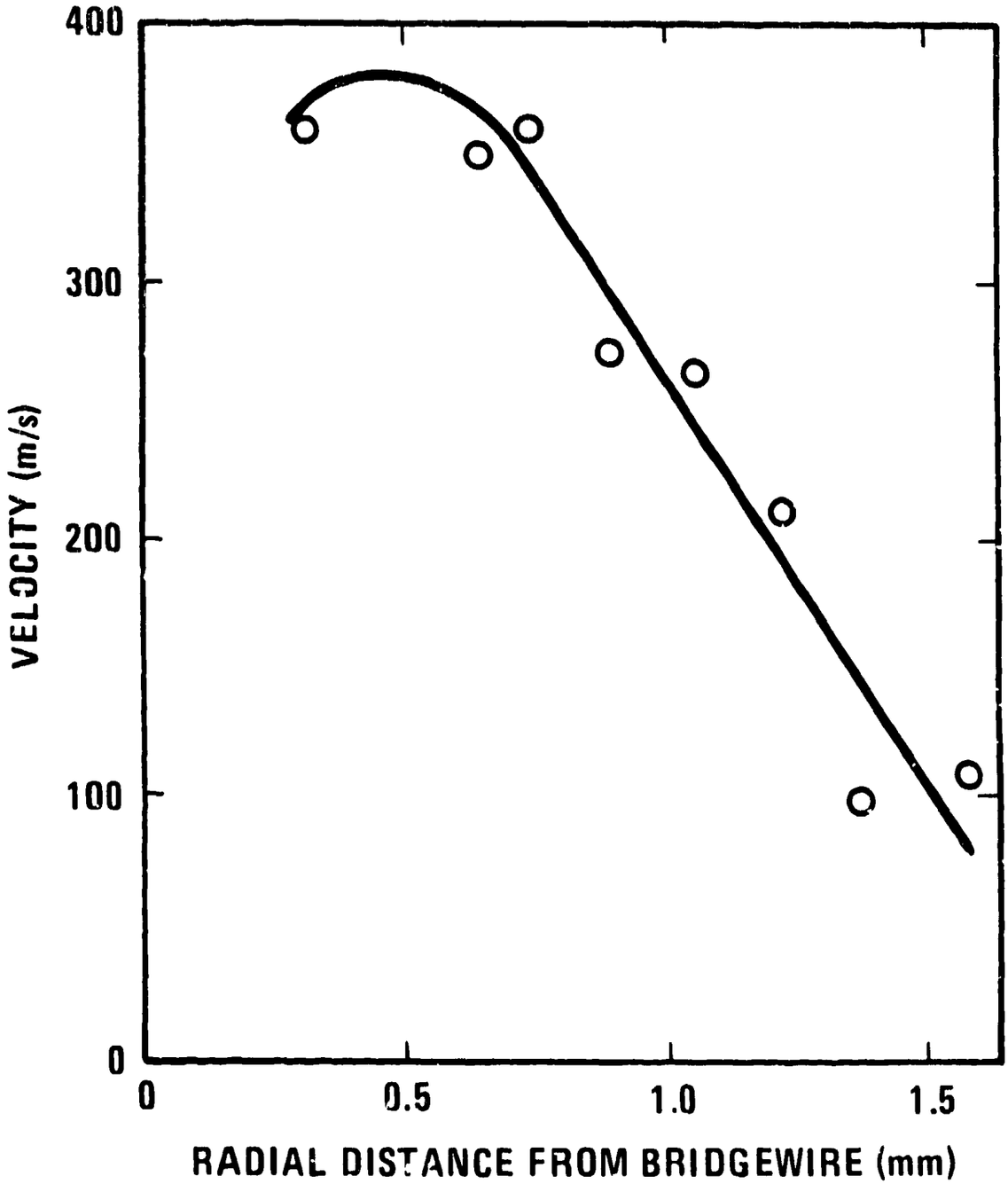

Fig. 2

Radial change in explosion velocity
Firing Voltage = 1000 V

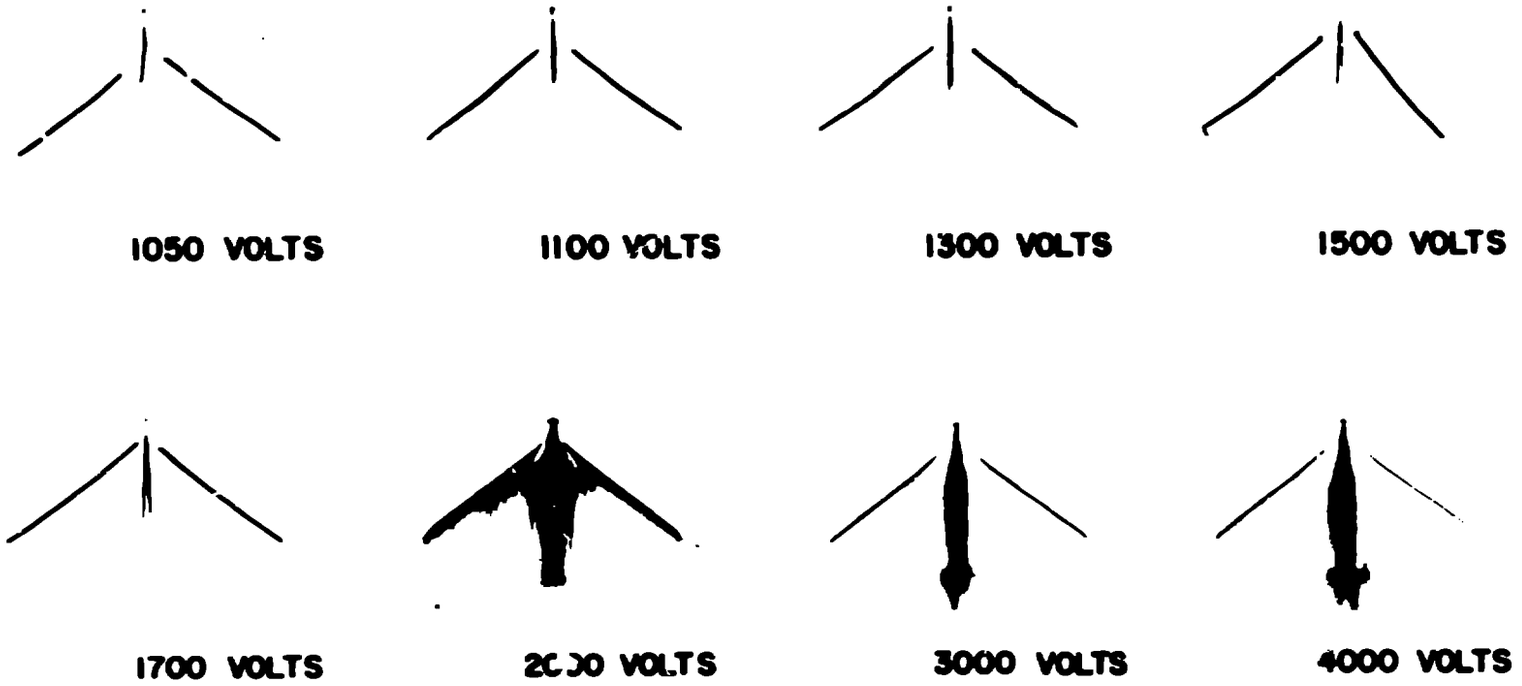

Fig. 3

Buildup to detonation traces
Various Firing Voltages

TABLE I

Time Delay of Onset of Explosion as a Function of Firing Voltage

Voltage (V)		Time Delay (μs)
1050	left side:	1.50
	right side:	1.22
1100		0.95
1300		0.82
1500		0.75
1700		0.68
2000		0.54
3000		0.48
4000		0.48

charged through the wire in contact with the explosive will initiate PETN to detonation with minimum delay.

The detonation velocity as a function of distance from the bridgewire is shown for two firing voltages in Figs. 4 and 5. To within the limits of experimental error the rate of buildup of velocity and the magnitude of the steady-state velocity are the same for the two conditions. The curves for other firing voltages intermediate to these two are similar. The radial distance from the bridgewire at which the stable velocity of PETN is reached is around six mm. The magnitude of the steady-state detonation velocity is about 5000 m/s. The on-axis steady detonation velocity in PETN charges of this size is about 5200 m/s and is reached at about three mm from the initiation area. Thus, the deflagration to detonation development is not perfectly spherical from the initiation source but more ellipsoidal with the highest rate oriented along the charge length.

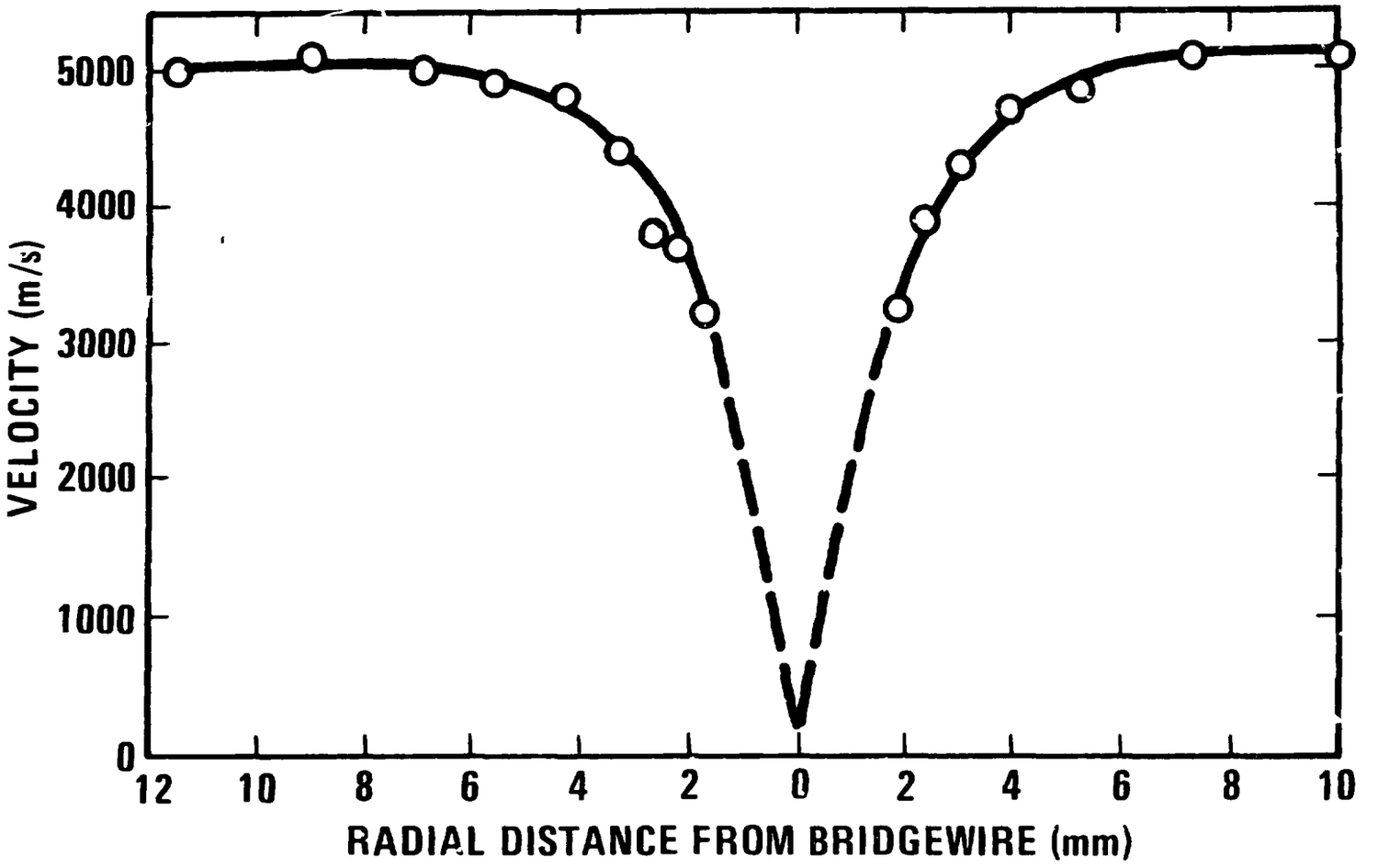

Fig. 4
Radial buildup to detonation.
Firing voltage = 1300 V

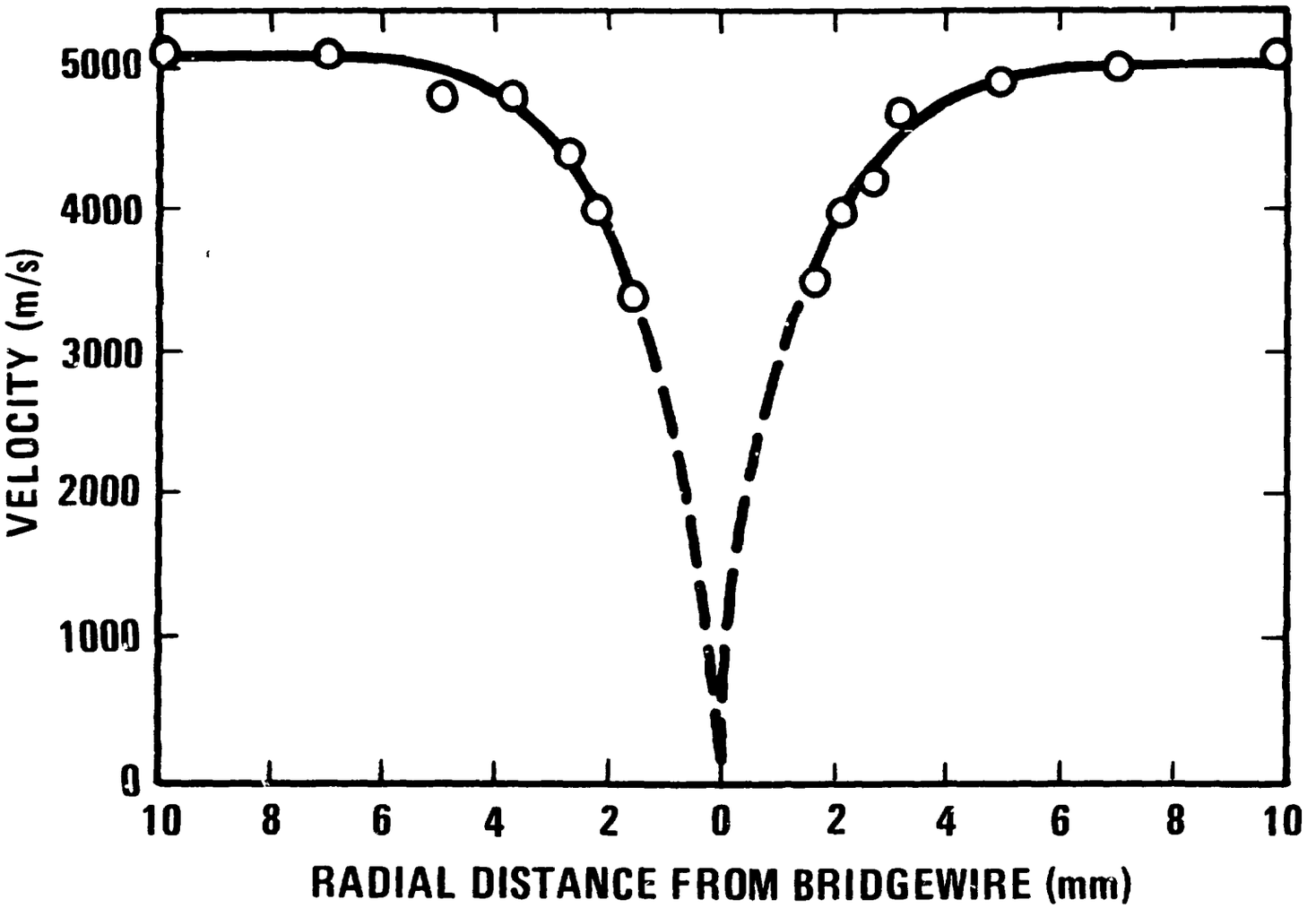

Fig. 5
Radial buildup to detonation.
Firing voltage = 4000 V