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UCRL-52273

SHOCK INITIATION OF PBXN-5 AND PBX-9604

L. G. Green
E. J. Nidick, Jr.
J. D. Longwith

April 29, 1977

Prepared for U.S. Energy Research & Development
Administration under contract No. W-7405-Eng-48

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Available from

National Technical Information Service

U.S. Department of Commerce

5285 Port Royal Road

Springfield, VA 22161

Price: Printed Copy \$; Microfiche \$3.00

<u>Page Range</u>	<u>Domestic Price</u>	<u>Page Range</u>	<u>Domestic Price</u>
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Preface

This report was prepared for the Department of the Army, Harry Diamond Laboratories, Adelphi, Maryland 20783, HDL Project A77646, under the auspices of the U.S. Energy Research & Development Administration under contract No. W-7405-Eng-48.

Contents

Abstract	1
Introduction.	1
Experimental.	2
Discussion	6
Acknowledgment	7
References	7

SHOCK INITIATION OF PBXN-5 AND PBX-9604

Abstract

The PBXN-5 and PBX-9604 shock Hugoniot, longitudinal and shear sound velocities, and response to long and short duration shocks have been determined. At a density of 1.66 Mg/m^3 , PBXN-5 requires a minimum

copper flyer kinetic energy of 382 kJ/m^2 for initiation at a flyer velocity of 0.8 km/s . At a density of 1.49 Mg/m^3 , PBX-9604 requires a minimum flyer energy of 201 kJ/m^2 for initiation at the same velocity.

Introduction

We have determined the experimental response of PBXN-5^{*} and PBX-9604[†] to strong shocks. The initiation experiments included both long ($3\text{-}\mu\text{s}$) and short ($<0.1\text{-}\mu\text{s}$) duration shocks. Shock Hugoniot data were obtained from symmetrical impacts of explosive on explosive. Longitudinal and shear sound velocities were obtained from ultrasonic measurements.

PBXN-5 Type I MIL-E-81111A(os) was purchased from the Naval Ships Parts Control Center, Mechanicsburg, Pennsylvania. Thermal analysis showed no unexpected behavior. PBX-9604 was

prepared at Lawrence Livermore Laboratory (LLL) according to a procedure outlined by Walker.¹ We found that PBX-9604 is the same as an experimental formulation prepared at LLL 10 or 15 years ago and known then as RX-10-AB. The latter was not pursued at that time, presumably because of the superior mechanical strength and pressability of PBX-9407,^{**} which was also available, and because of its very small gain in sensitivity over PBX-9407. There was also some fear that the low percentage of binder in RX-10-AB might cause a dust problem in automatic loading equipment.

^{*}PBXN-5 is 95/5 HMX/Viton A.

[†]PBX-9604 is 96/4 RDX/KelF 800.

^{**}PBX-9407 is 94/6 RDX/Exon 461.

Experimental

The principal features of sustained-pulse, shock-initiation experiments with the 101.6-mm gun have been described elsewhere.^{2,3} The current experiments differed from previous ones in that the explosive samples were only 25.4 mm in diameter and were impacted four at a time. A typical experiment consisted of impacting a group of four explosive samples with a thick (6-mm), copper, gun-propelled flyer plate and timing the transit of the shock wave plus detonation through these samples. Excess transit time (XSTT) was then calculated, where XSTT is defined as the observed transit time of the shock plus detonation minus the calculated time for transit of the detonation through the same thickness of explosive. Impact pressure was calculated from the velocity of the flyer, the known Hugoniot equation of state of the flyer, and the measured Hugoniot equation of state of the explosive being tested. Results were then plotted as the log of the XSTT versus the log of the initiating pressure, an approximately linear relationship reported by Ramsay and Popolato.⁴ Results from the tests on PBXN-5 and PBX-9604 are summarized in Fig. 1.

As the foil thickness (and the energy per unit area) is reduced, the XSTT observed will increase until the

Fig. 1. Excess transit time versus sustained-pulse initiating pressure for PBXN-5, PBX-9604, and PBX-9407. Data for PBX-9407 are from Lindstrom.⁶ Note similarity between PBX-9407 and PBXN-5 data.

detonation fails to propagate. Short-pulse initiation experiments therefore consist of thin-foil experiments tailored to give at least twice the XSTT that a comparable thick-plate experiment would give. The minimum or "critical" energy of initiation, E_c , is calculated from the empirical equation²

$$(X - 1)(Y - E_c) = C,$$

where X is the reduced XSTT, Y is the kinetic energy of the flyer plate per

unit area, and C is a constant that varies from one explosive to another. Reduced XSTT is the observed XSTT from a particular short-pulse experiment divided by the XSTT that would have resulted from a comparable sustained-pulse experiment. Ideally, only experiments where the reduced XSTT exceeds two are used to estimate minimum initiation energy.

For the short-pulse initiation experiments, we used the same 101.6-mm

gun and general experimental layout as for the sustained-pulse experiments; however, the flyer was a carbon-foam-backed copper foil⁵ instead of a thick (6-mm) copper plate. Results from all short-pulse, energy-limited, initiation experiments on PBXN-5 and PBX-9604 are summarized in Tables 1 and 2.

For the Hugoniot equation-of-state experiments, we used the same 101.6-mm gun facility as for the other

Table 1. Results of the short-pulse (energy-limited) initiation experiments on PBXN-5 (using a copper flyer plate).

Density of explosive (Mg/m ³)	Flyer plate thickness (mm)	Impact velocity (km/s)	Initial pressure (GPa)	Flyer plate kinetic energy (kJ/m ²)	Excess transit time (μs)	Minimum flyer energy for initiation (kJ/m ²)
1.658	0.127	0.798	3.62	361	No det., 11 mm	>361
1.661	.127	.798	3.62	361	No det., 7.5 mm	>361
1.660	.132	.793	3.60	371	No det., 11 mm	>371
1.664	.132	.793	3.60	371	No det., 7.5 mm	>371
1.665	.132	.793	3.60	371	No det., 11 mm	>371
1.666	.132	.793	3.60	371	No det., 7.5 mm	>371
1.658	.137	.788	3.55	380	No det., 7.5 mm	>380
1.658	.137	.788	3.55	380	No det., 11 mm	>380
1.666	.137	.788	3.55	380	No det., 7.5 mm	>380
1.667	.137	.788	3.55	380	No det., 11 mm	>380
1.660	.141	.805	3.67	407	0.605	358
1.663	.141	.805	3.67	407	0.778	372
1.658	.157	.800	3.63	450	0.552	392
1.660	0.157	0.800	3.64	450	0.665	406

Best value: 382

experiments. A 3.2-mm-thick disk of target explosive was impacted by a disk of the same explosive propelled down the gun barrel in a sabot. We measured the transit time of the shock and calculated the average shock velocity. Particle velocity after impact was taken as half of the projectile velocity. The shock

velocity at zero particle velocity was taken as the bulk sound velocity C_o calculated from the ultrasonic longitudinal sound velocity C_l and shear sound velocity C_s by the equation

$$C_o^2 = C_l^2 - \frac{4}{3} C_s^2.$$

Table 2. Results of the short-pulse (energy-limited) initiation experiments on PBX-9604 (using a copper flyer plate).

Density of explosive (Mg/m ³)	Flyer plate thickness (mm)	Impact velocity (km/s)	Initial pressure (GPa)	Flyer plate kinetic energy (kJ/m ²)	Excess transit time (μs)	Minimum flyer energy for initiation (kJ/m ²)
1.490	0.084	0.806	3.02	243	1.146	219
1.493	.084	.806	3.02	243	0.952	213
1.488	.089	.805	3.01	257	0.603	202
1.491	.089	.805	3.01	257	0.456	173
1.491	.089	.805	3.01	257	0.538	192
1.492	.089	.805	3.01	257	0.575	198
1.487	.102	.812	3.05	299	0.367	179
1.490	.102	.812	3.05	299	0.420	205
1.492	.102	.812	3.05	299	0.494	228
1.492	.102	.812	3.05	299	0.401	198
1.489	.127	.798	2.97	361	0.371	226
1.492	.141	.805	3.02	407	0.349	263
1.493	.141	.805	3.02	407	0.291	186
1.487	.157	.800	2.98	450	0.279	178
1.489	0.157	0.800	2.98	450	0.319	261
						<u>Best Value:</u> 201

Table 3. Results of Hugoniot experiments on PBXN-5 and PBX-9604. Zero particle velocity shock velocity data is calculated from ultrasonic longitudinal and shear velocity measurements.

Explosive	Particle velocity, U_p (km/s)	Measured shock velocity, U_s (km/s)	Density of target explosive (Mg/m ³)	Density of flyer explosive (Mg/m ³)
PBXN-5	0	1.133	1.661	—
	0	1.220	1.662	—
	0.329	2.112	1.659	1.661
	0.403	2.267	1.661	1.667
	0.432	2.394	1.661	1.666
	0.479	2.506	1.660	1.666
PBX-9604	0	0.996	1.491	—
	0	0.967	1.488	—
	0.298	1.704	1.491	1.493
	0.299	1.810	1.495	1.491
	0.397	1.950	1.489	1.489

Results are summarized in Table 3 and also in Fig. 2, along with a least-squares fit to the data. The points calculated from the ultrasonic data were given equal weight with the other data points.

Fig. 2. Shock velocity U_s versus particle velocity U_p for PBXN-5 and PBX-9604. The bulk sound velocity C_0 has been taken as the intercept of the shock velocity axis. The PBXN-5 data may be represented by the equation $U_s = 1.178 + 2.779 U_p$ km/s; that for PBX-9604 by $U_s = 0.987 + 2.509 U_p$ km/s.

Discussion

PBX-9604 is more sensitive than PBXN-5 to both sustained-pulse initiation and to energy-limited, short-pulse initiation. It appears that the higher percentage of voids in PBX-9604 (17.9%) at its working density compared to that in PBXN-5 (12.3%) at its working density is largely responsible for the difference observed in the sustained-pulse experiments. PBX-9407, which is made with the same kind of RDX as PBX-9604 but which has only an 11.1% void volume as it is normally used, has about the same sensitivity to sustained-pulse initiation as PBXN-5.⁶ It should be noted that the sustained-pulse experiments measure the rate of buildup of detonation in an explosive from a given stimulus, while the energy-limited, short-pulse experiments measure the minimum stimulus that will still result in detonation. Thus, the percentage of voids has a large influence on the rate of buildup of detonation.

The intrinsic sensitivity of the explosive (as opposed to the sensitivity due to voids) appears to be responsible for a large fraction of

the sensitivity to short-pulse initiation. PBX-9407 at its normal working density requires the flyer to have a kinetic energy of about 277 kJ/m^2 (Ref. 7), which is closer to the 202 kJ/m^2 required for PBX-9604 than it is to the 382 kJ/m^2 required for PBXN-5, even though the sensitivity of PBX-9407 to sustained-pulse initiation is similar to that of PBXN-5. Thus, the similar intrinsic sensitivity of the RDX in PBX-9604 and PBX-9407 results in their similar sensitivity to a short-pulse initiation. Because the percentage of voids has some effect, PBX-9604 is more sensitive than PBX-9407 even though made from the same kind of RDX.

As a final comment, we should mention that minimum or critical energy for initiation is pressure dependent for some (if not most) explosives.^{3,8} The very wide pressure range of constant critical energy for PBX-9404 reported by Walker and Wasley⁹ may be more the exception than the rule. The pressure dependencies of the critical or minimum initiation energies for PBXN-5 and PBX-9604 were not determined in these experiments.

Acknowledgment

The authors would like to express their gratitude and appreciation to W. Mumper, M. Bainter, and W. Duguid for their help with the 101.6-mm gun; to A. Brown and D. Green for their help with the ultrasonic measurements; and to W. Gummer and G. Moody for preparing the PBX-9604 used in these experiments.

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