LA-UR-95- 2762

CONF-950846--33

TITLE: WEDGE TEST DATA FOR THREE NEW EXPLOSIVES: LAX112, 2,4-DNI, AND TNAZ

AUTHOR: L. G. Hill, W. L. Seitz, J. F. Kramer, D. M, Murk, and R. S. Medina , LANL
Los Alamos, NM 87545

SUBMITTED TO: 1995 APS Topical Conference on "Shock Compression of Condensed Matter"
August 13-18, 1995 - Seattle, WA

WEDGE TEST DATA FOR THREE NEW EXPLOSIVES: LAX112, 2,4-DNI, AND TNAZ *

L.G. HILL, W.L. SEITZ, J.F. KRAMER, D.M. MURK, and R.S. MEDINA

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

High pressure Pop-plots and inert Hugoniot curves have been measured for three new explosives: LAX112 (3,6-diamino-1,2,4,5-tetrazine-1,4-dioxide), 2,4-DNI (2,4-dinitroimidazole), and TNAZ (1,3,3-trinitroazetidine). LAX112 and 2,4-DNI are of interest because of their insensitivity, while TNAZ is useful for its performance and castability. The shock sensitivity of LAX112 and 2,4-DNI fall between that of pressed TNT and PBX9502, LAX112 being the less sensitive. The shock sensitivity of TNAZ falls between that of pressed PETN and PBX9501. The Pop-plot and Hugoniot data for TNAZ matches well with the lower pressure gas-gun data of Sheffield, Gustavsen, & Alcon (to be discussed separately at this meeting). The inert Hugoniots for all three materials are comparable to those of other explosives.

INTRODUCTION

LAX112 (3,6-diamino-1,2,4,5-tetrazine-1,4-dioxide), Fig. 1a, was developed at Los Alamos in an effort to find an insensitive high explosive with better performance than TATB. LAX112 is distinguished by its very high nitrogen content and the absence of nitro groups. It has a high detonation velocity (≈ 8.3 mm/μsec),

but cylinder tests show that its metal pushing performance, while marginally better than TATB, is significantly below that of HMX, RDX, and PETN based explosives.(1)

2,4-DNI (2,4-dinitroimidazole), Fig. 1b, is another candidate for an insensitive high explosive. However, it should be noted that its impact sensitivity has been observed to vary by as much as a factor of three between batches, the suspected reason being small amounts of 4-Nitroimidazole impurities.(1) The detonation velocity of 2,4-DNI is slightly less than that of LAX112 (≈7.8 mm/μsec), but it's metal pushing performance appears to be slightly better.(2)

TNAZ (1,3,3-trinitro- azetidine), Fig. 1c, first appeared in the open literature in 1990,(3) but was initially of little practical interest due to excessive synthesis cost. Efforts at Los Alamos to find alternative synthesis routes(4) have been successful, and TNAZ is, at the time of this paper, starting to be manufactured in production quantities by the Aerojet corporation. TNAZ is very promising in that it has a performance similar to HMX but is melt castable. Thus it is a potential replacement for octols, cyclotols, and even HMX-based PBX's in many applications.

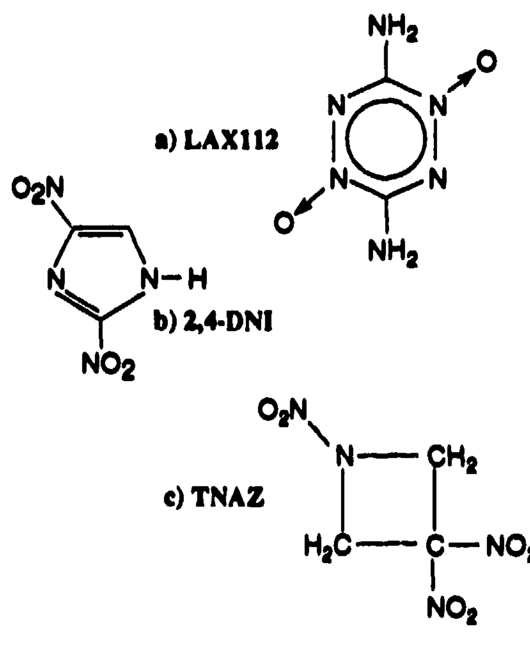

FIGURE 1. Molecular structures of LAX112, 2,4-DNI, and TNAZ.

*This work supported by the US Department of Energy.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

EXPERIMENT

Sample Preparation

The LAX112 and 2,4-DNI materials were both plastic-bonded formulations. The samples were ram-pressed to cylindrical shape, sawn on a diagonal to form two wedges, then machined along the saw cuts to achieve a good finish.

The LAX112 samples were formulation X-0535, composed of 95 wt.% LAX112 and 5 wt.% OXY 461.(1) The molding powder was pressed at 42,000 psi and 110 C to achieve about 97.8% of the 1.829 g/cc formulation TMD. X-0535 was found to have excellent mechanical properties—it was dimensionally stable, and pressed and machined well.

The 2,4-DNI samples were formulation X-0552, composed of 95 wt.% 2,4-DNI and 5 wt.% Estane. The molding powder was pressed at 42,000 psi and 90 C to achieve about 98.4% of the 1.720 g/cc formulation TMD.(2) X-0552 pressed and machined rather poorly, and the quality of the data is correspondingly lower than for the other two materials.

TNAZ has a critical temperature far above its melting point so that it can be melt cast or hot-pressed. The TNAZ wedges were neat-pressed at 42,000 psi and 97 C directly to the final wedge shape. The densities achieved were between 99.1% and 99.4% of the 1.840 g/cc TMD, which alleviates concern about density variations near the corner opposite the pressing die. The sample quality using this technique was excellent.(2)

Description of the Wedge Test

There have been many variations on the wedge test over the years; we used the so-called "mini-wedge" test of Seitz,(5) as shown in Fig. 2. The sample is small (about 7 g) and so restricts the run distance to about 1 cm. But for new explosives existing only in small quantities, material minimization is critical. The driver system was a 7.8-inch diameter plane wave lens, a 2-inch thick pad of booster explosive, and up to three attenuator plates to tailor the pressure delivered to the sample.

The diameter of the circular wedge face was 1 inch and the wedge angle was 30 degrees. This angle must be less than the "critical" at which release waves travel into the material, so that the propagation of the shock/detonation wave will be unaffected by that boundary. The critical angle is rarely known precisely, but 30 degrees is considered sufficiently conservative for all materials. The elliptical face of the wedge is glued to the last attenuator plate, the circular face thus serving as the observation surface. This configuration allows for a slightly longer run distance before the release wave from the opposite free boundary affects the measurement.

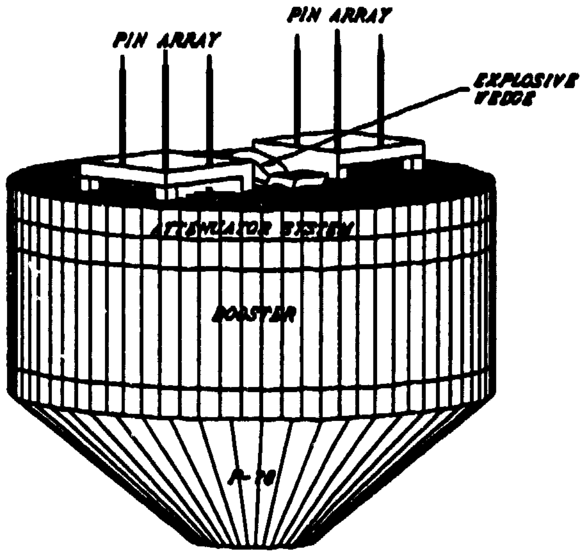

FIGURE 2. Schematic Drawing of the Wedge Test (Drawing by Herbert Harry).

The assembly in Fig. 2 is suspended upside down with the observation surface of the wedge parallel to the ground. Viewed from the side the wedge then appears as in Fig. 3a, and viewed from below as in Fig. 3b (with the attenuator plate now at 30 degrees to the ground). The image of the internal slit aperature is centered upon the wedge and, since the line of focus lies on the observation surface, there is no magnification variation or depth of field issue. The wedge is illuminated with an argon bomb, so that specularly reflected light from the observation surface is directed into the camera as in Fig. 3a. As the shock/detonation wave breaks out of the observation surface its reflectivity decreases and the light is attenuated as in Fig. 3b. Thus the wavefont appears as a curve of discontinuous exposure on the film.

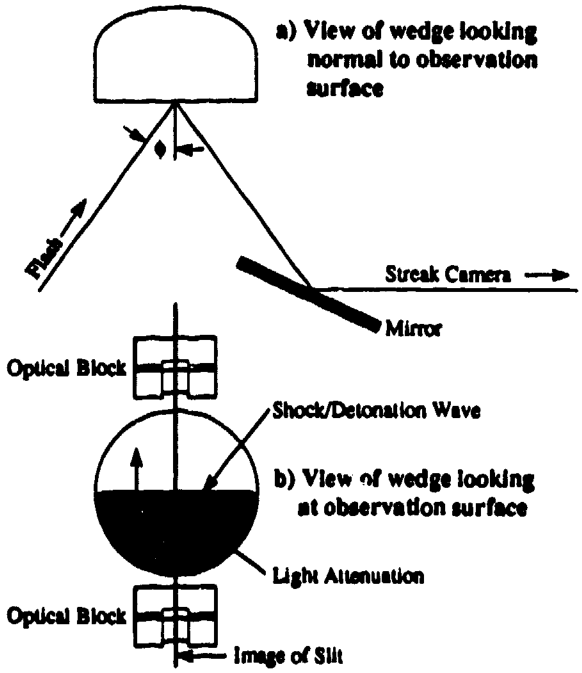

FIGURE 3. Optical configuration.

The other needed information is the free surface velocity of the final attenuator plate as the shock wave breaks out. Two methods were used for redundancy. In the first, two plexiglas blocks with shallow machined notches on one side were glued, notch side down, to the last attenuator plate, one on either side of the wedge and in the field of view of the streak camera slit (Fig. 3b). A thin layer of white paint was applied to the notch side of the blocks prior to gluing, so that the surface was initially reflecting to the flash light. When the free surface stikes the white paint the reflectivity decreases, first at the surface glued to the plate, and then at the recessed surface of the notch. The free surface velocity is determined from the optically measured time delay and the known notch depth. The second method involved two clusters of four piezoelectric pins spaced in increments of 0.5 mm from the plate (Fig. 2). As the free surface strikes the pins a voltage spike is produced. An x-t diagram is constructed from the known spacings and measured rise times, and the velocity is found from the slope of a fit to the points as $x \rightarrow 0$. With good data the two meathods typically agree to within a few percent.

ANALYSIS

The film record was read by optical comparitor. For a heterogeneous explosive one ideally sees a constant initial slope associated with the initial shock velocity, followed by a fairly well-defined kink associated with transition, followed by a (smaller) constant slope associated with detonation. Since the acceleration of the wave is never instantaneous, transition is somewhat ambiguous. Here the transition coordinates were measured directly from the film, and were taken to be the first perceptable departure from the slope associated with constant detonation velocity. By consideration of the present geometry one finds that the run distance x^* and the time to detonation t^* are related to the film coordinates X^* and Y^* by

$$x^* = x_{toe}\cos\theta + \frac{X^*\sin\theta}{mag}, \quad t^* = \frac{Y^*}{WrtSpd}, \quad (1)$$

where x_{toe} is the thickness of the wedge "toe" (it is never possible to achieve a knife edge), θ is the wedge angle, mag is the magnification, and $WrtSpd$ is the camera writing speed. The shock/detonation wave velocity is related to the angle of the film trace ψ by

$$U_{s/d} = \left(\frac{WrtSpd}{mag}\right)\sin\theta\cot\psi. \quad (2)$$

The input shock to the explosive is ideally a step rise to constant pressure, and its amplitude is inferred by impedance match. The necessary ingredients are 1) the Hugoniot of the final attenuator plate, 2) the measured free-surface velocity of the final attenuator plate, 3) the measured initial shock velocity in the explosive, and 4) the initial density of the explosive. From this one can deduce the initial particle velocity in the explosive (hence the inert Hugoniot) and the initial pressure in the explosive (hence the Pop-plot). We make the assumption that the isentrope of the reflected release wave from the free surface of the final attenuator is a reflection of the shock Hugoniot about the initial particle velocity. This is a good approximation for metal attenuators and, by comparison to more sophisticated methods, appears to be well within experimental error.

RESULTS

Run to detonation vs. input pressure (Pop-plot) for the three explosives is shown in Fig. 4 along with four common reference explosives. The sensitivity of LAX112 and 2,4-DNI both fall between that of pressed TNT and PBX9502, LAX112 being the less sensitive. The sensitivity of TNAZ falls between that of pressed PETN and PBX9501. Lower pressure gas-gun data for TNAZ,(6) also shown, agree well with the high-pressure wedge data.

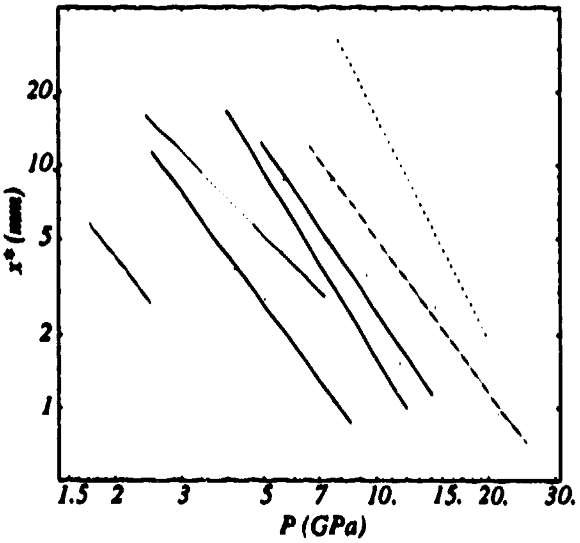

FIGURE 4. Run distance to detonation vs. input pressure (Pop-plot) points and linear fits for LAX112, 2,4-DNI, TNAZ, and selected other explosives.

The u_p-u_s Hugoniot is shown in Fig. 5, along with that of PBX9502. The curves are all similar, reflecting the fact that the inert properties of most high explosives are similar. Note that for the TNAZ data there is one less data point on the Hugoniot plot than on the Pop-plot. This is because at the highest input pressure the run distance was too short to measure an accurate initial shock speed, yet the transition point could be still be deciphered on the film. In such cases the Hugoniot based on the other points was used to calculate pressure for the Pop-plot point.

The numerical values of the data points are given in Table 1. The times to detonation transition are also included.

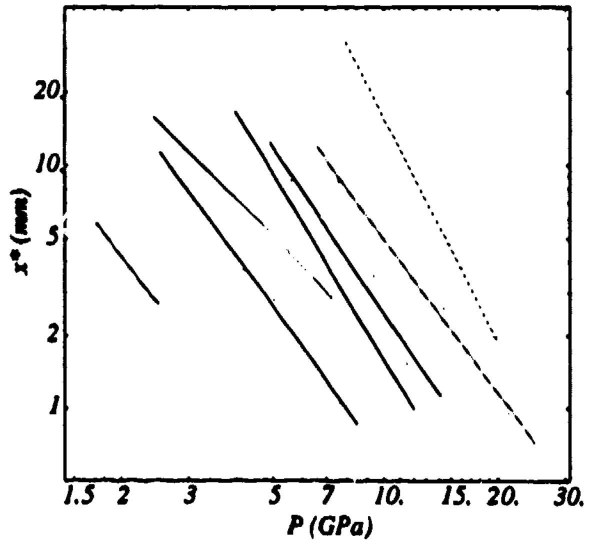

FIGURE 5. Inert Hugoniot points and linear fits for LAX112, 2,4-DNI, TNAZ, and PBX9502.

Table 1. Numerical values of the data points.

HE	ρ_0 g/cm^3	P_0 GPa	u_p km/s	U_s km/s	x^* mm	t^* μs
LAX112	1.793	7.5	0.95	4.41	8.00	1.67
	1.794	10.4	1.19	4.86	5.06	0.99
	1.794	13.7	1.41	5.43	2.12	0.36
	1.793	22.2	1.84	6.74	0.74	0.12
2,4-DNI	1.692	5.?	0.52	3.80	8.62	2.09
	1.692	9.4	0.87	4.76	3.52	0.72
	1.692	11.5	0.90	5.1?	1.53	0.31
TNAZ	1.825	2.9	0.47	3.42	8.18	2.36
	1.826	3.9	0.57	3.80	3.73	1.08
	1.826	5.0	0.70	3.95	2.80	0.69
	1.828	7.6	0.93	?.??	1.06	0.34

REFERENCES

1. Kramer, J. F., et al. "Insensitive High Explosives Program", Los Alamos Rpt. LA-12568-PR (1992).
2. Kramer, J. F., et al. "Insensitive High Explosives Program", Los Alamos Rpt. LA-12806-PR, V.1, (1993).
3. Archibald, T.G., et al., *J. Org. Chem.*, 55, 2920 (1990).
4. Coburn, M. D., and Hiskey, M. A., "An Alternate Synthesis of 1,3,3-Trinitroazetidine.", Los Alamos Rpt. #LA-CP-93-148 (1993).
5. Seitz, W. L., "Short-Duration Shock Initiation of Triaminotrinitrobenzene (TATB)", in *Shock Waves in Condensed Matter*, J. R. Asay et al., eds. (1983).
6. Sheffield, S. A., et al., "Hugoniot and Initiation Measurements on TNAZ Explosive", These proceedings.