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The increased shock sensitivity of PBX 9502 at high temperature

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Abstract. A modified gap test using brass attenuators has been designed that can significantly heat explosive samples prior to testing. The sensitivity of PBX 9502 when heated to 180, 200, 230 & 260°C and soaked for 30 minutes was investigated. It was discovered that under the moderate confinement (0.46 MPa) of this test, the sensitivity of the material did increase close to literature data for LX-17 (a very similar composition) heated to 250°C under heavy confinement.

1. Introduction

Previous tests of TATB-containing explosives that are heated (PBX 9502, LX-17 etc.) have demonstrated increased sensitivity to shock stimuli (e.g. figure 1). TATB based PBXs at operating mode temperatures are IHE materials that are difficult to detonate even intentionally and this is a significant safety feature. It is therefore important to understand the behavior of these materials under accident conditions, for example in explosive packages exposed to fire.

The purpose of this project was to examine the increase in sensitivity of PBX 9502 when heated to 180, 200, 230 & 260°C for 30 minutes in a modified LANL gap test geometry. In this way, the potential change in shock sensitivity behavior could be quantified prior to any more focused research program designed to probe areas of possible concern with respect to plausible accident scenarios. Data on the sensitivity of PBX 9502 at ambient conditions can be found in [1].

In a gap test, an explosion from a characterized and constant booster is attenuated across a variable thickness gap and the minimum thickness required to cause detonation in the acceptor explosive found. Thus, more sensitive explosives have larger gaps than insensitive ones. In this series, brass attenuators were employed as 'gaps'.

2. Experimental

The geometry used was a modified version of the LANL gap test discussed by Lam [3]. The principle difference between this geometry and previous small gap test designs is the larger booster diameter relative to the acceptor explosive diameter. This larger ratio introduces a more planar shock into the acceptor explosive that makes the test more representative of a 1D test and more importantly, results in a greater discrimination be between go and no-go gap thicknesses than more traditional divergent input shocks. The hot temperatures desired for these tests necessitated modifications that allowed the booster and detonator system to be kept remote from the hot main body containing the PBX 9502 pellets. This was necessary since the

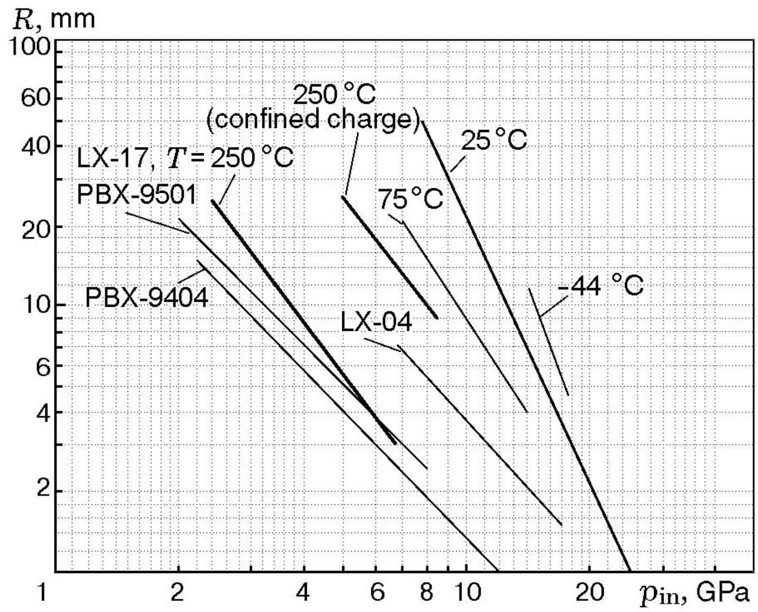

Figure 1. A comparison of the Pop plot data for LX-17 (a TATB composition similar to PBX 9502) as a function of temperature, from [2]. The -44, 25, 75°C curves are also LX-17.

1 inch diameter by 0.5 inch thick PBX 9501 booster used will rapidly deflagrate when exposed to temperatures above 200°C, as would the PETN in the Nonel detonator. The detonator/booster assembly was pushed by an air ram via a disposable polycarbonate rod into contact with the hot gap assembly a few seconds before intentional detonation.

The geometry used is shown in figure 2 & figure 3. One of the more difficult engineering challenges was managing the large thermal expansion of the two stacked 0.5 inch diameter by 0.5 inch long PBX 9502 cylinders, while keeping the acceptor face in firm contact with the brass attenuator. This was solved by using a steel spring that pushes on the steel piston (that took the place of a traditional witness block) up against the acceptor explosive and hence against the brass attenuator. Therefore, the effective action of thermal expansion was only away from the attenuator face.

The free surface critical diameter for PBX 9502 has been determined to be $\approx$ 9 mm [4]. Because the acceptor pellets are fitted into a supporting sleeve and are $\approx$ 12.7 mm in diameter, a supported detonation is therefore expected even at room temperature.

A PTFE sleeve held and aligned the steel piston and PBX 9502 pellets so that shock and acoustic waves caused by the booster explosion that coupled in into the aluminum body did not travel into the acceptor pellets ahead of the main shock. Such pre-shocks might potentially shock desensitize the explosive in marginal detonation cases. PTFE is a high temperature polymer with a low sound speed and is therefore ideal for this isolation purpose.

For all the tests reported here a piano wire compression spring with a constant of 62.4 lbs/inch was used. Calculating the nominal compression from the fixture design and the area of the piston and pellet, a nominal confining pressure of $\approx$ 0.46 MPa is calculated on the acceptor explosive. This would seem to count as moderate confinement.

Both the booster and PBX 9502 pellets were die pressed to minimize the expense of the experiments. The average density of the PBX 9502 was 1.892 ± 0.008 g/cc and the average density of the PBX 9501 boosters were 1.812 ± 0.002 g/cc. A band heater and thermocouple diagnostic (not shown) were employed via a PID electronic controller to heat and monitor the

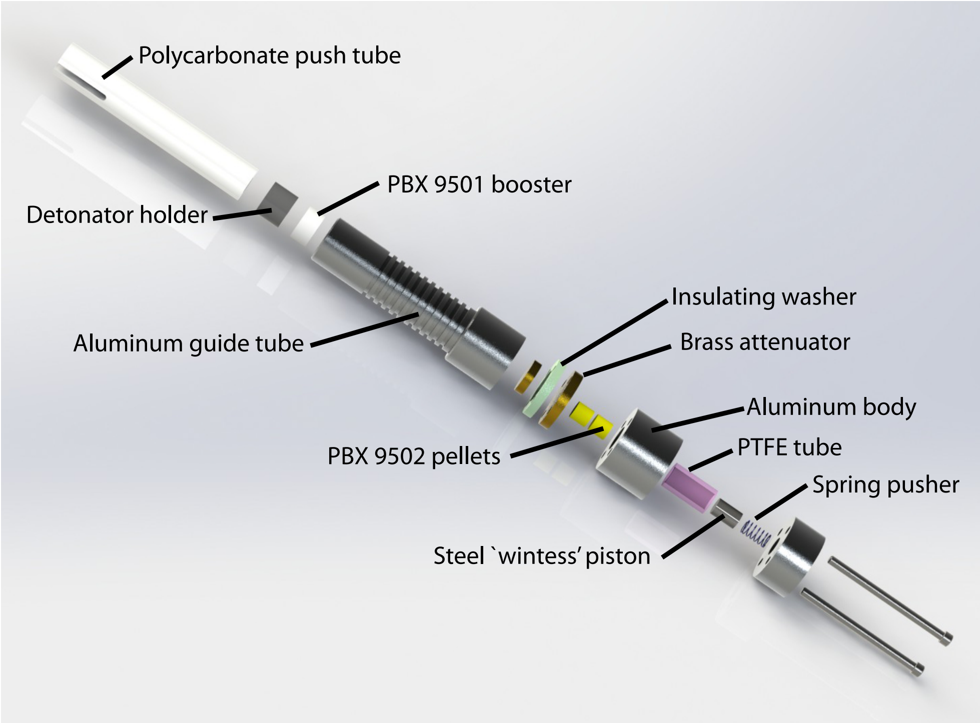

Figure 2. An 'exploded' view of the experiment.

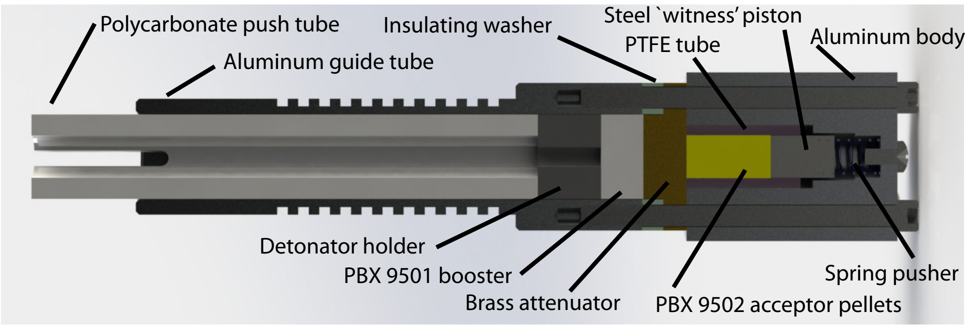

Figure 3. The side cross-section of the experiment in the closed, or testing, position.

body temperature of the assembly. The 30 minute soak at the desired temperature prior to detonation ensured that the pellets reached thermal equilibrium.

3. Results

A staircase methodology was used to discover the minimum gap, at a given temperature, for detonation in the PBX 9502. It was discovered that owing to a serendipitous internal reflection in detonating PBX 9502, an unambiguous dimple was created in the 'witness' piston in 'go' cases, while in 'no-go' cases the piston was almost undamaged. At each temperature, two repeats at a given gap were undertaken to generate the data in table 1.

Table 1. Measured brass gap thicknesses for PBX 9502 as a function of temperature.

Material	Temperature / °C	Gap / mm
PBX 9502	25	< 1
”	180	3.75±0.25
”	200	4.75±0.25
”	230	4.5±0.5
”	260	5.5±0.5
PBX 9501	25	10±0.5

4. Discussion

The data in table 1 show a clear increase in sensitivity of PBX 9502, at least in this geometry, when at elevated temperature. Reference [2] suggests that in unconfined LX-17 (a very similar composition to PBX 9502), a 1D shock sensitivity similar to PBX 9501 is created at 250°C, however, when the same material is heavily confined in a steel container, the Pop Plot is only slightly more sensitive than material at 75°C. What was meant by heavy confinement is not clear from the cited report. This confinement effect suggests that the primary method of sensitization of the composition is the formation of more effective, or more numerous, hot spot locations, not the reduced additional thermal heating required for reaction. The key question is therefore, what confinement is required to suppress this sensitization effect.

In our gap test geometry, the PBX 9502 is slightly confined by the spring pressure and probably between the two cases displayed in figure 1. For comparison, the gap thickness for PBX 9501, with the booster system used in the tests reported here, is around 10 mm at 25°C. Therefore, even at 260°C, the sensitivity of PBX 9502 under moderate confinement is substantially lower than PBX 9501.

Computer models in CTH were run to estimate the shock pressure into the PBX 9502 as a function of attenuator thickness. The results are shown in table 2 together with the associated run-to-detonation distance for LX-17 at 25°C taken from figure 1. Since it has been identified that at 25°C a gap of less than 1 mm is required for detonation to occur in PBX 9502, it implies that a run-to-detonation of less than 5 mm needs to occur in this particular test geometry before side releases erode the shock enough that full detonation does not occur. This appears reasonable since if the releases are assumed to enter at 45°, the 12.7 mm diameter would suggest erosion of the shock at approximately 6 mm of run. Because the real run-to-detonation was not measured in these tests, it is not possible to put exact points on the Pop-plot as a function of temperature, however, a region can be identified and this is illustrated in figure 4. Again, it is apparent that even under moderate confinement, PBX 9502 at 260°C is not nearly as sensitive as PBX 9501 under ambient conditions.

Table 2. The variation of shock pressure and run-to-detonation as a function of attenuator thickness using CTH modeling and [2].

Gap Thickness / mm	Input Pressure / GPa	Run to Detonation at 25°C / mm
1	15.5	5
3	13	9
4	12	12
5	11	16

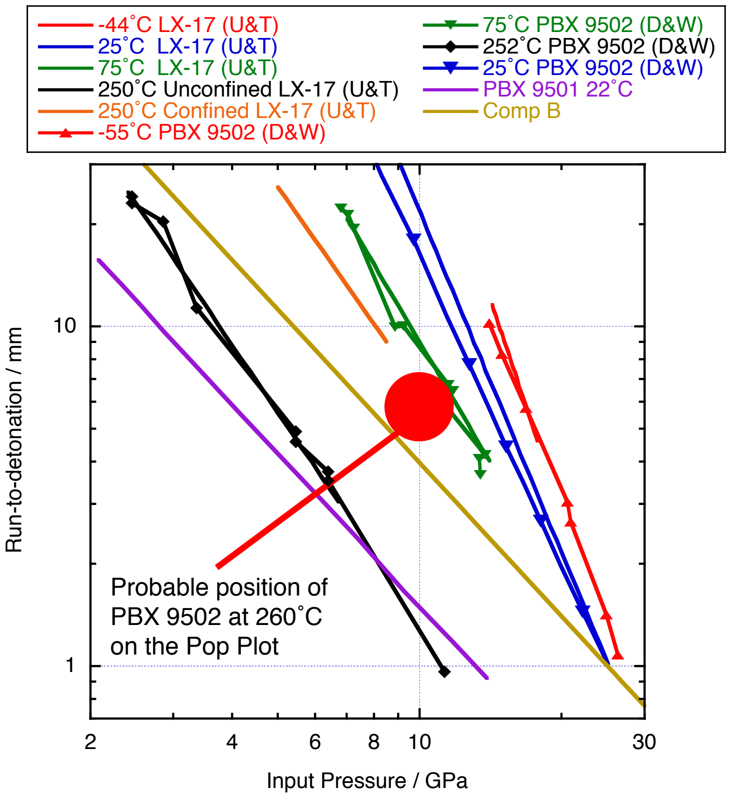

Figure 4. An illustration of the possible sensitivity of PBX 9502 in the gap test. Data from [5, 2, 4]

5. References

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