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A COMPARISON OF THERMAL EXPLOSIONS IN PBX 9501 AND PBX N-9

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Abstract. We have used a variety of observables to study the response of HMX based energetic materials formulations to thermal stimuli. In this paper, we compare the response of PBX 9501 and PBX N-9 to a temperature of 205 °C. Both undergo thermal runaway at this boundary condition with similar preignition behavior. However, the post-ignition burn propagations of the two formulations are very different with the final reaction violence significantly lower for PBX N-9 than for PBX 9501.

Keywords: PBX9501, HMX, thermal explosion, laser ignition
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INTRODUCTION

The formulations PBX 9501 and PBX N-9 are both high HMX content plastic bonded explosives. However, their responses to thermal stimuli are quite different. In this paper, we describe experiments looking at the pre-ignition thermal decomposition of these formulations, the evolution of ignition, and the final burn propagation for these formulations in a radial thermal explosion configuration.

EXPERIMENTAL PROCEDURE

The materials used in this study were PBX N-9, initial density 1.74 g/cc and composed of 92 wt% HMX, 6 wt% DOA, and 2 wt% Hytemp 4454, and PBX 9501, initial density 1.83 g/cc and composed of 95 wt% HMX, 2.5 wt% nitroplasticizer, and 2.5 wt% estane. Details of the radial thermal explosion are given in previous publications[1,2]. The experiment uses a cylinder of explosive heated from the outside by resistive wire heaters and held at a final soak temperature. Diagnostics are placed at the center of the explosive where the thermal runaway occurs. These diagnostics include thermocouples for pre-ignition thermal decomposition study, fiber optics for fast temperature measurements and laser synchronization, strain gauges on the outside of the case, and proton radiography to measure density evolution during both pre-ignition and burn propagation regimes. The temperature trajectory is shown in Fig 1.

RESULTS AND DISCUSSION

The pre-ignition behavior of PBX N-9 is similar to that of PBX 9501. The beta to delta phase transition endotherm is observed as a temperature dip lasting ~10 minutes at the 178 °C boundary temperature. The HE begins to exotherm immediately with a boundary temperature of 205 °C as seen in Figure 1. The time to ignition for PBX N-9 is longer than the time to ignition with the same boundary temperature for PBX 9501 with time to ignition of ~39 minutes for PBX N-9 compared to ~23 minutes for PBX 9501 at 205 °C boundary temperature.

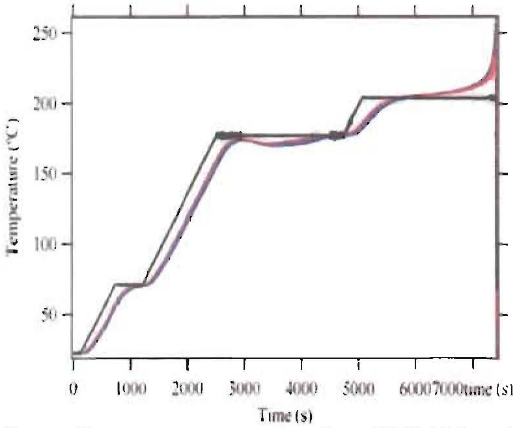


Fig. 1: Temperature verses time for a PBX N-9 radial thermal explosion experiment. Black lines are boundary temperature, colored lines are measured in the HE.

The post-ignition behaviors of the two formulations show significant differences. The first evidence for this difference is the postmortem analysis of the residue. Figure 2 shows the remainder from PBX N-9 and PBX 9501 radial experiments with the same applied temperature boundaries. The PBX 9501 is completely consumed, the aluminum sidewalls are fragmented, and the end caps have discs punched out where the HE was. In contrast, the PBX N-9 experiments remain largely intact after ignition and burning. Approximately 50% of the HE remains after the thermal explosion and the aluminum case is distorted, but not fragmented. Typically the endcaps are not punched out and are only slightly deformed from flat. The PBX 9501 is seen in proton radiography images to balloon out from a cylinder to a sphere during the approximately hundred microseconds of the thermal explosion event.

Fig. 2: Postmortem photos of PBX N-9 (top) and PBX 9501 (bottom) thermal explosions.

The proton radiography of the PBX N-9 thermal explosion event allows one to observe the post-ignition burn propagation and to measure the density loss caused by the HE burning. Fig. 3 shows one frame of the density evolution movie taken during the thermal explosion event. This frame was collected 320 microseconds after the onset of the central ignition. A line profile is taken a few millimeters from the midplane of the shot.

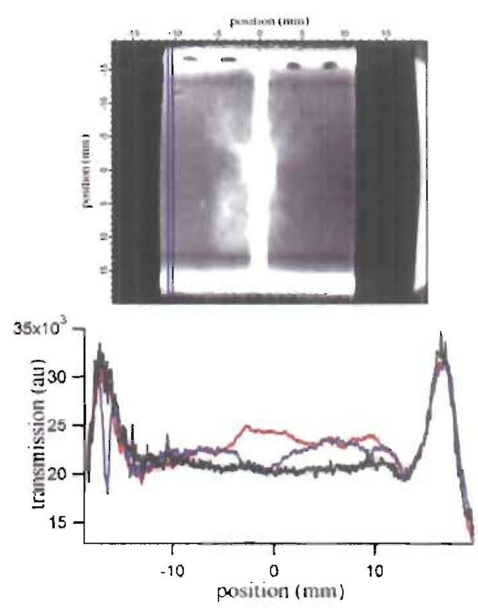


Fig 3. Proton radiograph taken 320 microseconds into thermal explosion. Below image are vertical line profiles of image at various locations.

Fig 3b shows the density profile at different distances from the midplane of the shot at this particular frame time. The maximimum density loss occurs at the midplane with a decrease in density of 60% of the initial HE density. Further from the midplane, density loss is approximately 40%, and furthest from the midplane, near the endcaps, there is little density loss.

There are 23 proton radiographs collected at 16 μs time intervals during the thermal explosion event. By taking a line profile across the midline of the images and overlaying the profiles for all images, a burn velocity can be extracted by tracking the edge position as a function of time. Fig 4 shows these overlaying line profiles. The burn velocity extracted from them shown in Fig. 5 is 10m/s. A similar analysis for burn velocities conducted on PBX 9501 yields axial velocities of approximately 200 m/s.

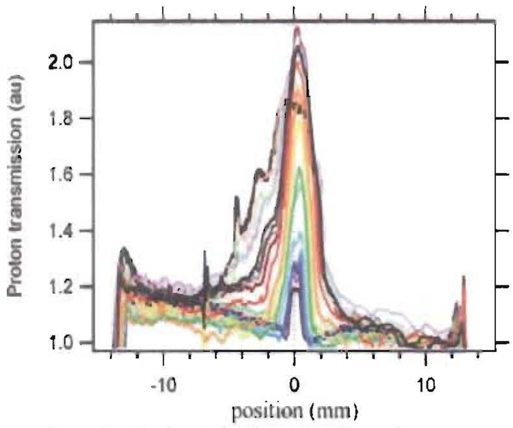


Fig. 4 Horizontal line profiles from proton radiographs of PBX N-9 thermal explosion taken from time 0 to time 384 microseconds into the event.

Fig 6 compares the proton radiographs for thermal explosions of PBX 9501 and PBX N-9. [1,3,4] The top 3 images are taken 20 microseconds apart during a PBX 9501 thermal explosion event. The first frame is early in the event and shows cracking from the midplane and what we believe to be gas escaping from the midplane opening. The 2nd frame taken 20 microseconds later shows the aluminum case has been distorted from a cylinder to more spherical. By the 3rd frame 40 microseconds after the first, the midplane has opened, the case has been severely distorted and the aluminum has begun to fragment. In comparison, the bottom 3 images are taken 64 microseconds apart. In the first frame, density loss and cracking from the midplane are observed. This pattern expands by the 2nd frame, 64 microseconds later, but has not yet reached the endcaps nor significantly distorted the aluminum cylinder. The final frame shows continued density loss and growth of the pattern, without any fragmenting of the aluminum cylinder and only slight bowing of the endcaps. The postmortem analysis of this shot shows that the state of the radial case does not change significantly after the final proton radiograph collected during the thermal explosion event. Fig 2 above shows what is left of the case after the shot has cooled back down to room temperature. There is damage evident at the midplane, and evidence of

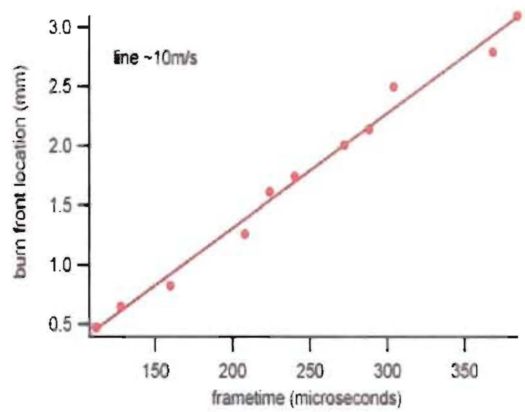
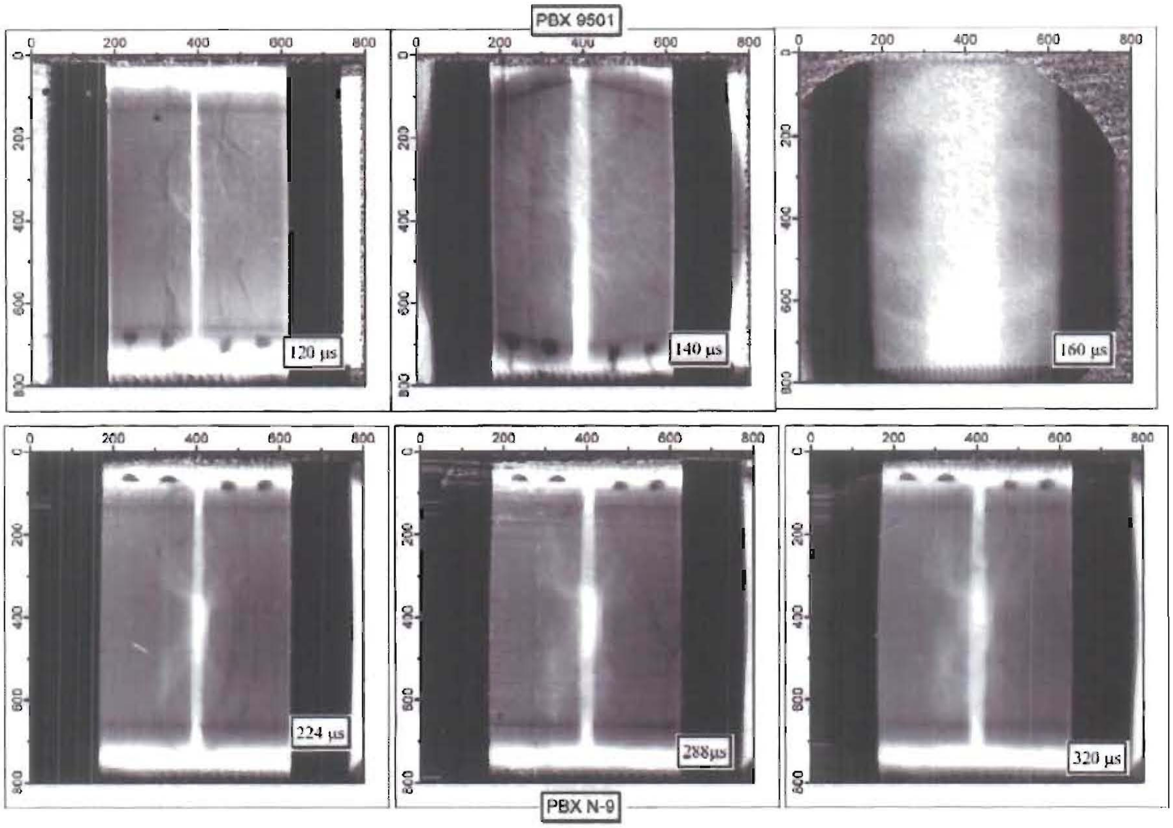


Fig 5: Burn velocity data extracted from profiles above.

hot gases having escaped. More than 50% of the PBX N-9 remains in the case and there is unconsumed HE found outside the case as well. Some wall and endcap bowing is seen.

CONCLUSIONS

The overall response of PBX N-9 in a thermal explosion is lower reaction rate, lower total energy, and lower reaction violence than for PBX 9501 under the same conditions. The post-ignition burn velocity for PBX N-9 is 20 times lower than PBX 9501, the total material consumed is approximately half, and there is significantly less damage to the confining case for PBX N-9 than PBX 9501. These observations are all consistent with a lower



pressure impulse and lower sustained pressure for the PBX N-9 thermal explosions.

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REFERENCES

1. Smilowitz, L.; Henson, B. F.; Romero, J. J.; Sandstrom, M. M.; Asay, B. W.; Schwartz, C.; Saunders, A.; Merrill, F.; Morris, C. L.; Murray, M. M.; McNeil, W. V.; Marr-Lyon, M.; Rightley, P.; collaboration, p. *Aip Conference Proceedings* **2007**, *955*, 1139.

2. Smilowitz, L.; Henson, B. F.; Romero, J. J.; Asay, B. W.; Schwartz, C. L.; Saunders, A.; Merrill, F. E.; Morris, C. L.; Kwiatkowski, K.; Hogan, G.; Nedrow, P.; Murray, M. M.; Thompson, T. N.; McNeil, W.; Rightley, P.; Marr-Lyon, M. *Physical Review Letters* **2008**, *100*, 228301.

3. Smilowitz, L.; Henson, B. F.; Sandstrom, M. M.; Asay, B. W.; Romero, J. J.; Collaboration, t. p. "The Evolution of a Thermal Explosion: Spatial and Temperature Profiles Internal to a PBX9501 Thermal Explsion"; International Detonation Symposium, 2006, Norfolk, VA.

4. Henson, B. F.; Smilowitz, L.; Romero, J. J.; Sandstrom, M. M.; Asay, B. W.; Schwartz, C.; Saunders, A.; Merrill, F.; Morris, C. L.; Murray, M. M.; McNeil, W. V.; Marr-Lyon, M.; Rightley, P.; collaboration, p. *Aip Conference Proceedings* **2007**, *955*, 825.