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TITLE EFFECTS OF BINDER CONCENTRATION ON THE PROPERTIES OF PLASTIC-BONDED EXPLOSIVES

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EFFECTS OF BINDER CONCENTRATION ON THE PROPERTIES OF PLASTIC BONDED EXPLOSIVES

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INTRODUCTION

This study was initiated to determine the effects of binder concentration on the properties of a PBX. The sensitivity of the estane/eutectic system used for PBX 9501 was not known as a function of concentration. The sensitivity of the system was of special interest when the energy was matched to PBX 9502. The behavior of PBX 9502-like systems is interesting because their unique mechanical properties, such as high strain to failure, might be designed into a useful formulation usable as a substitute for PBX 9501.

Desensitizing high-energy PBXs has another reason for understanding this work. One of the best important mechanisms for the initiation of explosives is believed to be hot spots caused by voids or other density discontinuities. High-energy PBXs, such as PBX 9501, typically can be prepared to 90% of theoretical density (TDH). This means that the explosive component has about 10% voids that may serve as hot spot locations. It appears that removing the voids is the logical starting place to desensitize a PBX.

EXPERIMENTAL

The experiments used in this study were the large-scale gap test and the plate dent test described by Gibbs and Popelka[3]. The plate dent test is a measure of the energy delivered by an explosive to a calibrated steel plate. It has been found experimentally that the delivered energy is closely related to the CJ pressure of the explosive being tested. A theoretical basis may be found for this relationship in such works as Fickett and Davis[4]. For this reason it is customary to calibrate the plate dent test to accepted CJ pressures and to report the results as CJ pressure. Because this pressure is a measure of the delivered energy, it will refer to the results of the plate dent test as the energy of the explosive.

A low void material was formulated to investigate the effect of the removal of voids from a PBX. The material to be tested was a formulation with 95% HMX and the estane/eutectic binder used in PBX 9501 (X.042/42.01.04 92/7/8% HMX/binder).

This formulation was chosen to provide more than eight binder to fill all the voids in the composite. To assure elimination of all voids, the PBX was pressed at unusually high pressure (30,000 psi) at maximum permissible temperature (240°F), with maximum vacuum on the powder before pressing, and with five intermittent loads. The resulting PBX had a density of 97.7% TDH. The CJ pressure and gap sensitivity were measured for this material; the results were 2.6 kbar and a gap sensitivity of 17 mm. This compares with values of 6 kbar and 16 mm for PBX 951. These data are included in Table 1. It is possible to formulate a PBX with less sensitivity than PBX 9501 to no loss in energy, perhaps even a small gain.

The prevailing conditions used to obtain the void-free samples of X.042/42.01.04 were rather extreme. A pressing evaluation was conducted to evaluate batch-to-batch of the material used in processing
TABLE 1. PERFORMANCE AND SENSITIVITY OF HIGH-BINDER PBX

<table>
<thead>
<tr>
<th>PBX</th>
<th>Propellant</th>
<th>Density</th>
<th>CJ Pressure</th>
<th>Gap Sensitive</th>
</tr>
</thead>
<tbody>
<tr>
<td>9501</td>
<td>94.5/5.5 7.5% HMX/Energetic</td>
<td>55.6</td>
<td>142</td>
<td>38.5</td>
</tr>
<tr>
<td>C-2424</td>
<td>94/6 7.5% HMX/Energetic</td>
<td>55.1</td>
<td>142</td>
<td>38.4</td>
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<tr>
<td>C-2424</td>
<td>94/6 7.5% HMX/Energetic</td>
<td>55.0</td>
<td>140</td>
<td>38.3</td>
</tr>
<tr>
<td>C-2424</td>
<td>94/6 7.5% HMX/Energetic</td>
<td>54.5</td>
<td>140</td>
<td>38.0</td>
</tr>
<tr>
<td>C-2424</td>
<td>94/6 7.5% HMX/Energetic</td>
<td>54.0</td>
<td>138</td>
<td>37.5</td>
</tr>
<tr>
<td>C-2424</td>
<td>94/6 7.5% HMX/Energetic</td>
<td>53.5</td>
<td>136</td>
<td>37.0</td>
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<tr>
<td>C-2424</td>
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<td>133</td>
<td>36.5</td>
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<tr>
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<td>94/6 7.5% HMX/Energetic</td>
<td>52.5</td>
<td>130</td>
<td>36.0</td>
</tr>
<tr>
<td>C-2424</td>
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<td>52.0</td>
<td>127</td>
<td>35.5</td>
</tr>
<tr>
<td>C-2424</td>
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<td>51.5</td>
<td>123</td>
<td>35.0</td>
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<tr>
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<td>51.0</td>
<td>118</td>
<td>34.5</td>
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<tr>
<td>C-2424</td>
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<td>50.5</td>
<td>112</td>
<td>34.0</td>
</tr>
<tr>
<td>C-2424</td>
<td>94/6 7.5% HMX/Energetic</td>
<td>50.0</td>
<td>106</td>
<td>33.5</td>
</tr>
<tr>
<td>C-2424</td>
<td>94/6 7.5% HMX/Energetic</td>
<td>49.5</td>
<td>100</td>
<td>33.0</td>
</tr>
<tr>
<td>C-2424</td>
<td>94/6 7.5% HMX/Energetic</td>
<td>49.0</td>
<td>94</td>
<td>32.5</td>
</tr>
<tr>
<td>C-2424</td>
<td>94/6 7.5% HMX/Energetic</td>
<td>48.5</td>
<td>87</td>
<td>32.0</td>
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<tr>
<td>C-2424</td>
<td>94/6 7.5% HMX/Energetic</td>
<td>48.0</td>
<td>80</td>
<td>31.5</td>
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<tr>
<td>C-2424</td>
<td>94/6 7.5% HMX/Energetic</td>
<td>47.5</td>
<td>73</td>
<td>31.0</td>
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<tr>
<td>C-2424</td>
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<td>47.0</td>
<td>66</td>
<td>30.5</td>
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<tr>
<td>C-2424</td>
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<td>46.5</td>
<td>59</td>
<td>30.0</td>
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<tr>
<td>C-2424</td>
<td>94/6 7.5% HMX/Energetic</td>
<td>46.0</td>
<td>52</td>
<td>29.5</td>
</tr>
</tbody>
</table>

This PBX formulation was responsible for the improved performance. All the variables used in the processing of X 0242-92 01 04 were varied from normal to extreme in an experimental design, and the density of the sample at these conditions was measured. The concentration of the binder and, to a lesser extent, the number of pressing intensifications were found to be the only variables that significantly influenced the densities of the pressed samples. The CJ pressure and the gap sensitivity were determined for one sample of X 0242-92 01 04 pressed under nominal pressing conditions. The results reproduced those of the formulation pressed under more extreme conditions. Improved sensitivity and HMX can be obtained by simply increasing the fraction of binder in the composite while using three intensifications.

To investigate in detail the behavior of the HMX/Energetic system, a number of formulations were made with HMX compositions varying from 90.5 to 94 wt%. These materials were pressed, the detonation pressures were determined with plate shot experiments, and the gap sensitivity was measured. These data are listed in Table 1, with the literature values for PBX 9501 included for reference.

All the HMX/Energetic materials listed in Table 1 made satisfactory pressing with the exception of the 90.5 wt% formulation. This material was extremely "p Sammy" and tended to extrude around the edges in the press. We were not able to obtain the desired density for this formulation. The properties of this material are interesting even though they are not directly comparable with the other formulations.

The first observation made from the data in Table 1 is that the gap sensitivity falls off dramatically as the HMX in the formulation is decreased, reaching a plateau at about 40 or 41 mm (Figure 1). The second observation is that the energy of the system remains relatively constant as the HMX in the formulation is decreased until the mixture is approximately 92 wt% HMX (Figure 2). This result does not seem too surprising, if one realizes that voids of zero energy are being replaced with an energetic binder. Looking at the results presented in Figures 1 and 2, one concludes that an improved version of PBX 9501 can be obtained by decreasing the HMX content to 92 wt%. The gap sensitivity will be decreased while the energy will remain constant.

![Figure 1: CJ Pressure as a Function of HMX Concentration](image1)

![Figure 2: Gap Sensitivity as a Function of HMX Concentration](image2)
reach very high per cent TMDs, the importance of reaching very high per cent TMDs is seen in Figure 4, where the gap sensitivity is plotted as a function of per cent TMD. It is apparent that a PBX should be at the maximum possible per cent TMD. To obtain the best sensitivity in a HMX/Eastane/eutectic formulation, it will be necessary to determine what controls the relatively small differences in pressing densities.

In conclusion, a series of PBXs has been formulated with more binder than is normally used in high energy explosives. It was determined that adding a relatively small amount of binder to a material such as PBX 9501 will improve the gap sensitivity without decreasing the energy or the explosive. It appears that the best compromise for a PBX 9501 type material is about 32 wt% HMX. Adding additional binder does not continue to improve the gap sensitivity of the formulation. However, the energy of the PBX decreases as expected. The high binder formulations are of potential use because of the possibility of formulating a PBX with energy similar to PBX 9502's but with a much higher strain to failure and other desirable advantages.

REFERENCES
