DEVELOPMENT OF AN ALTERNATE POLYISOBUTYLENE (PIB) BINDER FOR COMPOSITION C-4
DEVELOPMENT OF AN ALTERNATE PIB BINDER
FOR COMPOSITION C-4

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Outline

• Background
• Objective
• Approach
• Qualification
• Summary
Holston Army Ammunition Plant is the sole qualified producer of Composition C-4 in the U.S.

Composition C-4 is mainly used for demolition purposes
- M112 Demolition Charge
- M183 Demo Kit
- MICLIC
- M18A1 Claymore Mine

Nominal Composition C-4, Cl. 3
- Taggant 1.23%
- Binder 9.88%
- RDX Explosive 88.89%
• About 2.3% of the plastic binder in Composition C-4 is polyisobutylene (PIB)
• ExxonMobil has been the only qualified PIB producer - Vistanex MML-120
• ExxonMobil sold the Vistanex trade name to BASF and ceased its PIB production
• Vistanex PIB will not be available in CY08
• BASF will only market its own PIB – Oppanol
• PM-CCS initiated this effort to qualify BASF Oppanol PIB
Objective

• Qualify a new source of polyisobutylene for use as binder in Composition C-4
Approach

- Completed market survey
- Three grades of BASF Oppanol were analyzed for MIL-P-13298, polyisobutylene compliance

<table>
<thead>
<tr>
<th>Specification</th>
<th>MIL-P-13298 PolyIsoButylene Specification</th>
<th>BASF Oppanol B-100</th>
<th>BASF Oppanol B-150</th>
<th>BASF Oppanol B-200</th>
<th>ExxonMobil Vistanex MML-120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic Viscosity</td>
<td>3.15</td>
<td>3.72</td>
<td>3.250</td>
<td>5.177*</td>
<td>6.554*</td>
</tr>
<tr>
<td>Iodine No.</td>
<td>1.32</td>
<td>1.46*</td>
<td>0.7462</td>
<td>0.4048</td>
<td>0.89</td>
</tr>
<tr>
<td>Chlorine, %</td>
<td>0.10</td>
<td>&lt; 0.10</td>
<td>&lt; 0.10</td>
<td>&lt; 0.10</td>
<td>&lt; 0.10</td>
</tr>
<tr>
<td>Acidity, % AS HCL</td>
<td>0.01</td>
<td>0.011*</td>
<td>0.005</td>
<td>0.009</td>
<td>0.000</td>
</tr>
<tr>
<td>Insoluble Matter</td>
<td>0.20</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
<td>&lt; 0.20</td>
</tr>
<tr>
<td>Color</td>
<td>&lt;= standard</td>
<td>&lt; std</td>
<td>&lt; std</td>
<td>&lt; std</td>
<td>&lt; std</td>
</tr>
</tbody>
</table>

* Failed Specification
Approach

- Five lab-scale batches (2 lb/batch) produced with various Oppanol PIB grades meet MIL-C-45010 for Composition C-4

<table>
<thead>
<tr>
<th>Specification</th>
<th>MIL-C-45010A Comp C-4, Class 3 Specification</th>
<th>Comp C-4 with B-100</th>
<th>Comp C-4 with B-150</th>
<th>Comp C-4 with B-200</th>
<th>Comp C-4 with 70% B100 &amp; 30% B150</th>
<th>Comp C-4 With MML-120</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-4 Batch #</td>
<td></td>
<td>1039-100</td>
<td>1039-102</td>
<td>1039-103</td>
<td>1039-107</td>
<td>1039-105</td>
</tr>
<tr>
<td>% RDX</td>
<td></td>
<td>Min. 89.8 Max. 91.2</td>
<td>90.13</td>
<td>90.52</td>
<td>90.48</td>
<td>90.42</td>
</tr>
<tr>
<td>% Binder</td>
<td></td>
<td>8.8</td>
<td>10.2</td>
<td>9.87</td>
<td>9.48</td>
<td>9.52</td>
</tr>
<tr>
<td>% Moisture</td>
<td></td>
<td>0.25</td>
<td>0.0120</td>
<td>0.0048</td>
<td>0.0047</td>
<td>0.0047</td>
</tr>
<tr>
<td>USSS 40</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>USSS 60</td>
<td></td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Plasticity</td>
<td></td>
<td>0.018</td>
<td>0.052</td>
<td>0.052</td>
<td>0.023</td>
<td>0.037</td>
</tr>
</tbody>
</table>
Approach

• All 5 C-4 lab samples (4 test samples and 1 control) were rheological tested at the ARDEC Energetic Rheology Lab

• Instron Capillary Rheometer was used
  – Measures the apparent viscosity (Pa*s) versus the apparent shear rate (1/s)
  – Composition C-4 apparent viscosity decreases with increasing apparent shear rate

• Testing of lab samples yielded inconclusive results
  – Typical behavior of Composition C-4 not made on production-scale equipment
Approach

- Rheological testing all 5 lab samples (4 test samples and 1 control) at ARDEC yielded inconclusive results
  - Typical behavior of Composition C-4 not made on production-scale equipment

Figure 1: Typical Rheology Results of C-4 Production Batches
Qualification

• Oppanol B-150 and B-200 were selected for qualification:
  – B-100 fails 2 specification requirements on chemical properties
  – B-150 and B-200 fail on viscosity which may only affect their processing
  – Intrinsic Viscosity
    • Current specification for PIB appears to have been derived from the ExxonMobil own product specification
    • B-150 and B-200 have higher intrinsic viscosities
    • Intrinsic viscosity affects flow, i.e., the higher value, the more viscous is the product
  – Higher molecular weight PIB
    • More elastic
    • Higher recovery after extension

BASF Oppanol B-200 (20 kg)
Qualification

- Composition C-4 production batches have been produced
  - Three 4,000 lb batches with Oppanol B-150
  - Three 4,000 lb batches with Oppanol B-200
  - C-4 from a standard PIB Vistanex MML-120 production lot
  - All batches have been tested for MIL-C-45010A compliance

- Did not produce Composition C-4 batches having a blend of B-150 and B-200 (70% B-100/30% B-150)
  - No blending among the various PIB grades
  - Cross-blending may create potential complication due to the possibility that one of the product grades may be discontinued
  - PIB will be procured from a single source with two different grades
Qualification

- All 6 Composition C-4 production batches produced with Oppanol PIB meets MIL-C-45010 specification requirements

<table>
<thead>
<tr>
<th>Specification</th>
<th>MIL-C-45010A Comp C-4, Class 3 Specification</th>
<th>Comp C-4 with B-150</th>
<th>Comp C-4 with B-150</th>
<th>Comp C-4 with B-150</th>
<th>Comp C-4 with B-200</th>
<th>Comp C-4 with B-200</th>
<th>Comp C-4 With B-200</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-4 Batch #</td>
<td></td>
<td>C403-7577</td>
<td>C403-7578</td>
<td>C403-7579</td>
<td>C403-7580</td>
<td>C403-7581</td>
<td>C403-7582</td>
</tr>
<tr>
<td>Min.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% RDX</td>
<td>89.8</td>
<td>90.6</td>
<td>90.5</td>
<td>90.6</td>
<td>90.2</td>
<td>90.2</td>
<td>90.2</td>
</tr>
<tr>
<td>% Binder</td>
<td>8.8</td>
<td>9.4</td>
<td>9.5</td>
<td>9.4</td>
<td>9.8</td>
<td>9.8</td>
<td>9.8</td>
</tr>
<tr>
<td>% Moisture</td>
<td>0.25</td>
<td>0.03</td>
<td>0.02</td>
<td>0.01</td>
<td>0.07</td>
<td>0.04</td>
<td>0.05</td>
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<td>USSS 40</td>
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<td>0</td>
</tr>
<tr>
<td>USSS 60</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Plasticity</td>
<td>0.018</td>
<td>0.176</td>
<td>0.131</td>
<td>0.142</td>
<td>0.140</td>
<td>0.167</td>
<td>0.117</td>
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<tr>
<td>% DMDMB</td>
<td>1.00</td>
<td>1.14</td>
<td>1.30</td>
<td>1.40</td>
<td>1.38</td>
<td>1.18</td>
<td>1.16</td>
</tr>
</tbody>
</table>
Path Forward

• All Composition C-4 batches will be shipped to a Load/Assemble/Pack facility, either Crane Army Ammunition Activity and/or Milan Army Ammunition Plant for extrusion
  – Test IAW MIL-DTL-50523, M112 Demolition Charge
  – Evaluate extrusion performance with standard Composition C-4

• Complete qualification of Oppanol B-150 and B-200 at ARDEC with testing of thermal, sensitivity, performance, rheology characteristics, and aging evaluation of Composition C-4 with both PIBs
Summary

- Vistanex MML-120 polyisobutylene has been qualified for use in Composition C-4
- ExxonMobil, Vistanex MML-120 producer, will no longer manufacture PIB
- Vistanex will not be available in CY08
- BASF produces a similar PIB product named Oppanol
- Two grades of BASF Oppanol are being qualified for use in Composition C-4
  - Production test batches have been manufactured
  - Testing will soon be initiated