Development of Cast Cure Explosives for Comp B Replacement

Prepared by:
Robert Hatch, Paul Braithwaite, Nathan Seidner, and Jim Wright
ATK Launch Systems

May 11-14, 2009
NDIA IM/EM Technology Symposium, Tucson, AZ
Two cast cure formulations developed:

- Formulation DLE-C054 (RDX, NTO, HTPB binder)
- Formulation DLE-C055 (RDX, TEX, HTPB binder)

**Formulation Characterization**

- Formulation and processing features
- Small scale sensitivity
- Subscale performance testing
- Subscale Insensitive Munitions testing
A replacement explosive for Comp B must meet the following objectives:

- Low Cost
- High Performance
- Castable, with good processing characteristics
- Respond well to IM threats of impact, cookoff, and sympathetic detonation

Potential advantages of cast cure versus melt pour formulations:

- Problems with volume changes due to phase changes avoided
- Rubbery nature of binder provides damage resistance and improves response to impact events
- Cast cure charges usually contain low numbers of defects that can increase shock sensitivity
- Proven IM capabilities demonstrated in formulations such as PBXN-110 and PBXN-109
Formulation

- HTPB binder system
- 88% Solids
  - Coarse RDX
  - Coarse NTO (3-nitro-1,2,4-triazal-5-one)
  - Fine RDX

Processing

- Viscosity minimized by adjusting ratio of coarse and fine RDX
- Excellent processing with end-of-mix viscosities from 7-12 kp
- Material flows easily through slit or hole plate when casting
DLE-C054 Scale Up

• Made in ¼ pint, pint, 1-gallon, and 5-gallon mix sizes

• Scale up was straightforward with just slightly longer mix times at larger mix sizes

• End-of-mix viscosity and processing was identical at each mix size

• Expected to scale easily to production 600-gallon mixers

• ATK Launch Systems has mix facilities capable of producing millions of pounds per year
Excellent sensitivity

<table>
<thead>
<tr>
<th>DLE-C054 Sensitivity</th>
<th>Uncured</th>
<th>Cured</th>
<th>Class 5 RDX</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABL Impact (cm) – TIL</td>
<td>41</td>
<td>51</td>
<td>1.8</td>
</tr>
<tr>
<td>ABL Friction (lbs) – TIL</td>
<td>≥800 @ 8 ft/s</td>
<td>≥800 @ 8 ft/s</td>
<td>25 @ 6 ft/s</td>
</tr>
<tr>
<td>ABL ESD (J) - TIL</td>
<td>5.7</td>
<td>0.133</td>
<td>0.025</td>
</tr>
<tr>
<td>DSC Onset (°C)</td>
<td>221</td>
<td>216</td>
<td>219</td>
</tr>
</tbody>
</table>
Two dent/rate tests performed
- LSGT Hardware (13.97 cm long by 3.65 cm diameter charge)

Excellent performance
- Detonation velocity = 8.0 km/s (Comp B = 7.9 km/s)

<table>
<thead>
<tr>
<th>Dent Depth (DLE-C054)</th>
<th>Dent Depth (Comp B)</th>
<th>Percentage of Comp B</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.398”</td>
<td>0.433”</td>
<td>92%</td>
</tr>
</tbody>
</table>
Variable Confinement Cookoff Testing Performed

- Heat rate = 6°F/hr

<table>
<thead>
<tr>
<th>Wall Thickness (in.)</th>
<th>Reaction Temperature (ºF)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.030</td>
<td>342</td>
<td>burn</td>
</tr>
<tr>
<td>0.045</td>
<td>342</td>
<td>pressure rupture</td>
</tr>
<tr>
<td>0.075</td>
<td>341</td>
<td>pressure rupture</td>
</tr>
<tr>
<td>0.090</td>
<td>341</td>
<td>pressure rupture</td>
</tr>
<tr>
<td>0.120</td>
<td>341</td>
<td>deflagration</td>
</tr>
</tbody>
</table>

VCCT at heavy 0.12 inch confinement
- steel sleeve in one piece
- no fragmentation
Large Scale Gap Testing Performed (8 tests)

- 140 cards (compared to 201 for Comp B)
- Significant reduction in shock sensitivity compared to Comp B
DLE-C055 Formulation and Processing

Formulation

• HTPB binder system
• 88% Solids
  – Coarse RDX
  – Coarse TEX (4,10-dinitro-2,6,8,12-tetraoxa-4,10-diazatetracyclododecane)
  – Fine RDX

Processing

• Viscosity minimized by adjusting ratio of coarse and fine RDX
• Excellent processing with end-of-mix viscosities from 7-11 kp
• Material flows easily through slit or hole plate when casting
• Made in ¼ pint, pint, and 1-gallon mix sizes
TEX

- 4,10-dinitro-2,6,8,12-tetraoxa-4,10-diazatetracyclododecane
- Cheetah thermochemical code theoretical performance a little better than NTO
- Has been manufactured in the past at ATK Launch Systems
- Not currently manufactured in large quantities in the US
- Synthesis starts with inexpensive materials – has the potential to be reasonably low cost

Caged molecular structure results in high density of 1.99 g/cc
Excellent sensitivity

<table>
<thead>
<tr>
<th>DLE-C055 Sensitivity</th>
<th>Uncured</th>
<th>Cured</th>
</tr>
</thead>
</table>

A premier aerospace and defense company
Two dent/rate tests performed

- LSGT Hardware (13.97 cm long by 3.65 cm diameter charge)

Excellent performance

- Detonation velocity = 7.7 km/s (Comp B = 7.9 km/s)

<table>
<thead>
<tr>
<th>Dent Depth (DLE-C055)</th>
<th>Dent Depth (Comp B)</th>
<th>Percentage of Comp B</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.419”</td>
<td>0.433”</td>
<td>97%</td>
</tr>
</tbody>
</table>

Velocity Measurement

\[ y = 7.6855x - 1.6334 \]

\[ R^2 = 0.9969 \]
Large Scale Gap Testing Performed (6 tests)

- 141 cards (compared to 201 for Comp B)
- Significant reduction in shock sensitivity compared to Comp B
Summary and Conclusions

DLE-C054 is a promising composition for Comp B replacement

- Good performance
- Excellent shock sensitivity compared to Comp B
- Good small-scale slow cookoff response
- Excellent processing characteristics
- Potentially low cost

DLE-C055 has features very similar to DLE-C054 but with improved performance

- However, a good commercial source of large quantities of TEX is not available at this time