DLE-C067: A New Insensitive Cast-cure Formulation for Large Munition Use

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Acknowledgements

• Project team consisted of the following:
  – Program Management: Jared Olson, Bob Wardle
  – Investigators: Michael Adams, Paul Braithwaite
  – Technicians: Dean Child, Colton Potter, Marc Hall
  – Safety Testing: Josh Hill, Mindy Burnett, Lyle Merrill
  – Performance Testing: Todd Anderson, Russ Stuart, Terrel Christensen

• Formulating, mixing, casting and testing all performed at ATK facilities in Promontory, Utah
Background & Introduction

- DLE-C067 is a new cast-cure explosive
- It was developed as an IM-compliant explosive for use in large munition applications
- Large munition fills exhibit a mix of moderate brisance and high blast
- Poor IM response can be devastating based on size of munition alone
- Goals for this formulation:
  - Good performance similar to PBXN-109 and H-6
  - Combined effects
  - Low shock sensitivity and good IM response
Formulation Development – Approach

- DLE-C054 starting point
  - Cast-cure explosive with 88% solids containing RDX & NTO
  - Performance similar to Comp B
  - Demonstrated excellent IM response to all types of stimuli in subscale and full-scale testing
- Develop an aluminized version of DLE-C054
- Initial theoretical approach
  - Followed two branches of conceptual analysis approaching formulation from different directions
  - Adjusted formulations along these branches with focus on
    - Maintain total solids loading level
    - High detonation pressure
    - Good cylinder expansion energy
    - Moderate brisance
Formulation Development – Performance

- Made initial small mixes of two formulation modifications based on initial performance calculations
  - Both processed well, were castable, with good basic safety test results
- Down selected to a single formulation designated DLE-C067
  - Calculated properties, but formulation is very non-ideal so estimates are guidelines of potential relative performance only

<table>
<thead>
<tr>
<th>Calculated Property</th>
<th>DLE-C067 Properties Relative to</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DLE-C054</td>
</tr>
<tr>
<td>Theoretical Max. Density</td>
<td>103%</td>
</tr>
<tr>
<td>Pressure (C-J)</td>
<td>113%</td>
</tr>
<tr>
<td>Temperature (C-J)</td>
<td>125%</td>
</tr>
<tr>
<td>Shock Velocity</td>
<td>97%</td>
</tr>
<tr>
<td>Energy at V/Vo=7.2</td>
<td>111%</td>
</tr>
<tr>
<td>Mech. Energy</td>
<td>120%</td>
</tr>
</tbody>
</table>
Formulation Development – Processing/Safety

• Rheological properties
  – Measured viscosity at end of mix: 6 to 10 kP
  – Casts well

• Safety test data
  – Tested according to our standard safety testing protocols
  – Safe for handling and processing
  – Compared to RDX baseline for reference

<table>
<thead>
<tr>
<th>Test</th>
<th>Uncured</th>
<th>Cured</th>
<th>Class 5 RDX</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABL Impact (cm), TIL</td>
<td>26</td>
<td>64</td>
<td>1.8</td>
</tr>
<tr>
<td>ABL Friction (lbs), TIL</td>
<td>560 @ 8 ft/s</td>
<td>420 @ 8 ft/s</td>
<td>25 @ 6 ft/s</td>
</tr>
<tr>
<td>ABL ESD (J), TIL</td>
<td>1.305</td>
<td>No reaction</td>
<td>0.025</td>
</tr>
<tr>
<td>Bulk ESD (at 8 J)</td>
<td>---</td>
<td>No consumption</td>
<td>No mass ignition</td>
</tr>
<tr>
<td>SBAT Onset (°F)</td>
<td>324°F (162°C)</td>
<td>318°F (159°C)</td>
<td>378°F (192°C)</td>
</tr>
</tbody>
</table>
Formulation Development – Scale-up

• Mixes of DLE-C067 made from less than ¼ pint to 1-gallon scale
  – Same consistency and ease of casting at each mix size
  – Similarity in family leads to good scale-up potential beyond that
  – Other formulations have scaled up well such as DLE-C054

• From 1-gallon size mix, successfully cast subscale test items, including:
  – NOL Large Scale Gap Test (LSGT) pipes
  – Various sizes of cylindrical samples
Subscale Performance – Shock Velocity/Pressure

- Dent/rate testing performed using NOL card gap pipes with TOA pins along length of pipe
- Dent depth corresponds to 99% of PBXN-109 depth in same configuration
- Detonation velocity was higher than Comp B or PBXN-109

<table>
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<tr>
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<th>DLE-C067</th>
<th>DLE-C054</th>
<th>Comp B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Det. Velocity (relative)</td>
<td>105%</td>
<td>101%</td>
<td>100%</td>
</tr>
<tr>
<td>Plate Dent Depth (in.)</td>
<td>0.369</td>
<td>0.398</td>
<td>0.433</td>
</tr>
</tbody>
</table>
Subscale Performance – Critical Diameter

- Critical diameter measured using unconfined cylinders of various sizes lined up end to end on aluminum witness plates
  - TOA wires at end of samples to measure unconfined velocity
- Critical diameter measured between $\frac{1}{2}$-inch and $\frac{3}{4}$-inch

<table>
<thead>
<tr>
<th></th>
<th>1” dia.</th>
<th>$\frac{3}{4}$” dia.</th>
<th>$\frac{1}{2}$” dia. Dies out</th>
<th>$\frac{1}{4}$” dia. intact</th>
</tr>
</thead>
</table>
Subscale IM Performance – Shock Sensitivity

• Shock sensitivity measured by Large Scale Gap Test (LSGT)
  – Excellent shock sensitivity response, improved over DLE-C054

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<th>Comp B</th>
</tr>
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<tbody>
<tr>
<td>LSGT Gap Results (inch)</td>
<td>1.22</td>
<td>1.40</td>
<td>2.01</td>
</tr>
<tr>
<td>Corresponding Pressure (kbar)</td>
<td>49.7</td>
<td>44.3</td>
<td>20.7</td>
</tr>
</tbody>
</table>
A promising new cast-cure explosive, DLE-C067, has been developed for use in large munitions

- Formulation is an aluminized version of the excellent IM explosive DLE-C054

Formulation scale-up to 1-gallon scale has been straightforward

- Excellent safety properties and rheology
- No differences in processing characteristics based on mix size

Testing shows good balance of performance and low shock sensitivity

- Measured detonation velocity > Comp B or PBXN-109
- CJ pressure nearly identical to PBXN-109
- Reduced shock sensitivity relative to DLE-C054 & PBXN-109

Additional characterization in larger hardware expected to further highlight impressive properties of this newly developed formulation