Advances in Cast Cure Explosives

2009 NDIA IM & EM Technology Symposium
Tucson, AZ

May 11-14, 2009

Dr. Robert Hatch and Paul Braithwaite – ATK Launch Systems
Wendy Balas and Dr. Kenneth E. Lee – US Army ARDEC
Acknowledgements

Appreciation is extended to:

Ms. Wendy Balas and Dr. Kenneth E. Lee of ARDEC for their support of this advanced technology initiative

IM testing of 3.2” generic shaped charges:

Bullet and fragment impact performed by General Dynamics Ordnance and Tactical Systems under contract to ARDEC

Fast and slow cookoff performed by National Technical Systems’ National Ordnance, Munitions, and Environmental Test Center under subcontract to General Dynamics
Outline

Objective and approach

Performance

Processing

Subscale Insensitive Munitions (IM) testing
  • Shock sensitivity in LSGT
  • Slow cookoff in VCCT

IM testing in 3.2” generic shaped charge warheads
  • Bullet impact, fragment impact, slow cookoff, fast cookoff

Summary
Objectives and Approach

Objectives: Develop new cast cure explosives that meet the following criteria:

- Improved performance over PBXN-110 (for HMX formulations)
- Equivalent or better IM response than PBXN-110

Approach: Use a proven binder system which has given good IM and processing properties

- Formulate DLE-C051 to exceed PBXN-110 for metal-driving applications
- Formulate DLE-C050 to exceed PBXN-110 performance for dual purpose applications – metal driving and blast
- Formulate DLE-C053 to provide best cost and performance balance
Theoretical Performance

Cheetah performance prediction comparison to PBXN-110:

- DLE-C051 has 4.5% increase in Energy @V/V₀ = 6.5
- DLE-C050 has 31% increase in total mechanical energy (blast)
- DLE-C053 slightly lower energy than PBXN-110 but still very good

<table>
<thead>
<tr>
<th>Formulation</th>
<th>DLE-C050</th>
<th>DLE-C051</th>
<th>DLE-C053</th>
<th>PBXN-110</th>
</tr>
</thead>
<tbody>
<tr>
<td>P_c (Kbar)</td>
<td>247</td>
<td>264</td>
<td>231</td>
<td>249</td>
</tr>
<tr>
<td>V_d (km/s)</td>
<td>7.59</td>
<td>7.89</td>
<td>7.58</td>
<td>7.75</td>
</tr>
<tr>
<td>CJ Temperature (°K)</td>
<td>4734</td>
<td>3757</td>
<td>3768</td>
<td>3682</td>
</tr>
<tr>
<td>Energy @ V/V₀ = 6.5 (kJ/cc)</td>
<td>8.15</td>
<td>7.22</td>
<td>6.7</td>
<td>6.91</td>
</tr>
<tr>
<td>Total Mech Energy (kJ/cc)</td>
<td>11.46</td>
<td>9.10</td>
<td>8.6</td>
<td>8.77</td>
</tr>
</tbody>
</table>
Processing

One of the primary goals in the development of new castable explosives is to optimize processing.

Factors to consider include:
- Ability of binder to wet solids
- Final mix viscosity
- Flowability of explosive through typical casting tooling

Excellent flow of mixes and good casting quality

Cast surface of DLE-C050
Large Scale Gap Tests (LSGT) conducted

- Sensitivity similar to PBXN-110
- DLE-C053 used standard solid explosive
  - Opportunities to further improve shock sensitivity may be possible through the use of specially prepared material

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Go/No-go # Cards</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLE-C050</td>
<td>173/175</td>
</tr>
<tr>
<td>DLE-C051</td>
<td>176/177</td>
</tr>
<tr>
<td>DLE-C053</td>
<td>175/176</td>
</tr>
</tbody>
</table>
Relatively mild VCCT reactions were observed

- Sample heated at 6 °F/hour.
- Steel sleeve in two large pieces at 0.090” wall thickness

<table>
<thead>
<tr>
<th>Wall Thickness (in.)</th>
<th>Reaction Temperature (°F)</th>
<th>Reaction Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.030</td>
<td>359</td>
<td>burn</td>
</tr>
<tr>
<td>0.045</td>
<td>333</td>
<td>pressure rupture</td>
</tr>
<tr>
<td>0.060</td>
<td>360</td>
<td>pressure rupture</td>
</tr>
<tr>
<td>0.075</td>
<td>367</td>
<td>pressure rupture</td>
</tr>
<tr>
<td>0.090</td>
<td>342</td>
<td>deflagration</td>
</tr>
</tbody>
</table>

VCCT Test at 0.090 in. Wall Thickness
Relatively mild VCCT reactions were observed

- Sample heated at 6 °F/hour
- Steel sleeve in three large pieces at 0.090” wall thickness

### VCCT of DLE-C051

<table>
<thead>
<tr>
<th>Wall Thickness (in.)</th>
<th>Reaction Temperature (°F)</th>
<th>Reaction Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.030</td>
<td>360</td>
<td>pressure rupture</td>
</tr>
<tr>
<td>0.045</td>
<td>357</td>
<td>pressure rupture</td>
</tr>
<tr>
<td>0.060</td>
<td>358</td>
<td>pressure rupture</td>
</tr>
<tr>
<td>0.075</td>
<td>355</td>
<td>deflagration</td>
</tr>
<tr>
<td>0.090</td>
<td>371</td>
<td>deflagration</td>
</tr>
</tbody>
</table>
Device loaded with approximately 2 lb of explosive
Bullet impact, fragment impact, slow cookoff, and fast cookoff performed
Only DLE-C050 and DLE-C051 tested at this time

Schematic of Generic 3.2” Shaped Charge
Bullet Impact Testing of 3.2” Generic Shaped Charges

Single 50 caliber armor-piercing bullet targeted 5.75” from liner end

Test Monitoring
– Over pressure gages
– High speed digital video
– Standard video
– Witness plates
– Velocity screens

<table>
<thead>
<tr>
<th>Warhead Fill</th>
<th>Projectile Velocity</th>
<th>Gage Pressure Readings</th>
<th>Witness Plate Markings</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLE-C050</td>
<td>2865 ft/s</td>
<td>none</td>
<td>none</td>
<td>Type V (burn)</td>
</tr>
<tr>
<td>DLE-C051</td>
<td>2846 ft/s</td>
<td>none</td>
<td>none</td>
<td>Type V (burn)</td>
</tr>
</tbody>
</table>
Bullet Impact Testing of 3.2” Generic Shaped Charges

End closures dislodged from main body
Copper liners remained intact
Explosive fill ignited and burned
No debris thrown more than 50 ft

Recovered Explosive

DLE-C050

DLE-C051
Single conical mild steel projectile at ~6000 ft/s

Test Monitoring
- Over pressure gages
- High speed digital video
- Standard video
- Witness plates
- Velocity screens

<table>
<thead>
<tr>
<th>Warhead Fill</th>
<th>Projectile Velocity</th>
<th>Gage Pressure Readings</th>
<th>Witness Plate Markings</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLE-C050</td>
<td>6087 ft/s</td>
<td>none</td>
<td>none</td>
<td>Type V (burn)</td>
</tr>
<tr>
<td>DLE-C051</td>
<td>6110 ft/s</td>
<td>none</td>
<td>none</td>
<td>Type V (burn)</td>
</tr>
</tbody>
</table>
Fragment Impact Testing of 3.2” Generic Shaped Charges

Warhead cases split open by fragment impact
Debris scattered in the immediate vicinity of test stand
No debris thrown more than 50 ft

DLE-C050

DLE-C051
Slow Cookoff Testing of 3.2” Generic Shaped Charges

Slow cookoff performed at 6 °F/hour heating rate

Test Monitoring
- Over pressure gages
- Standard video inside and outside oven
- Witness plates
- Thermocouples of oven and skin temperature

<table>
<thead>
<tr>
<th>Warhead Fill</th>
<th>Reaction Temperature</th>
<th>Gage Pressure Readings</th>
<th>Witness Plate Markings</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLE-C050</td>
<td>350.0 °F</td>
<td>none</td>
<td>none</td>
<td>Type V (burn)</td>
</tr>
<tr>
<td>DLE-C051</td>
<td>353.4 °F</td>
<td>none</td>
<td>none</td>
<td>Type V (burn)</td>
</tr>
</tbody>
</table>
Slow Cookoff Testing of 3.2” Generic Shaped Charges

Warheads remained essentially intact and lay next to test stand

DLE-C050

Internal video showed extruding explosive deformed copper liners

DLE-C051

Gases vented past deformed liners after ignition
Fast Cookoff Testing of 3.2” Generic Shaped Charges

Fast cookoff performed above fuel basin containing 500 gallons of kerosene

Test Monitoring
– Over pressure gages
– Standard video
– Thermocouples for air temperature near test article

<table>
<thead>
<tr>
<th>Warhead Fill</th>
<th>Average Flame Temperature</th>
<th>Time to Ignition</th>
<th>Gage Pressure Readings</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLE-C050</td>
<td>1611 °F</td>
<td>33 s</td>
<td>none</td>
<td>Type IV (deflagration)</td>
</tr>
<tr>
<td>DLE-C051</td>
<td>1768 °F</td>
<td>13 s</td>
<td>none</td>
<td>Type V (burn)</td>
</tr>
</tbody>
</table>
Fast Cookoff Testing of 3.2” Generic Shaped Charges

Small pieces of burning explosive thrown to 30 ft
Copper liner ejected past 50 ft
DLE-C050 main body found 9 ft from test stand in fuel basin

DLE-C051 body and liner remained in wire basket and burned (melted) in the fire

DLE-C050

DLE-C051
An advanced weapon and space systems company

Summary

Two new cast cure explosives developed
• DLE-C050 and DLE-C051
• Compositions have predicted performance better than PBXN-110

Characterization started on a third promising formulation in this family of cast cure explosives (DLE-C053)
• Low cost and high performance

Formulations have excellent processing characteristics

Shock sensitivity similar to PBXN-110

IM response of DLE-C050 and DLE-C051 excellent in 3.2” shaped charges

<table>
<thead>
<tr>
<th>Warhead Fill</th>
<th>Bullet Impact</th>
<th>Fragment Impact</th>
<th>Slow Cookoff</th>
<th>Fast Cookoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLE-C050</td>
<td>Type V (burn)</td>
<td>Type V (burn)</td>
<td>Type V (burn)</td>
<td>Type IV (deflagration)</td>
</tr>
<tr>
<td>DLE-C051</td>
<td>Type V (burn)</td>
<td>Type V (burn)</td>
<td>Type V (burn)</td>
<td>Type V (burn)</td>
</tr>
</tbody>
</table>