Development of Electrically Controlled Energetic Materials for 120mm Tank Igniters

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Distribution Statement A: Approved for public release; distribution is unlimited.
**Electrically Controlled Energetic Materials**  
(ECEMs)

- Hydroxylammonium nitrate (HAN) based plastisol
  - Formulations developed by Digital Solid State Propulsion (DSSP)
- Developed as a replacement for ammonium perchlorate
- Generates relatively non-toxic gases
- Burn rate controlled through electrical parameters
Motivation

• Benite – Inconsistent ignition, inconsistent performance

*Reproduced from Rozumov 56th JPM

High speed video stills from static test firing of 120mm M865 tank igniters*

• Future igniter materials
  • Performance – Consistent ignition with the ability to throttle
  • IM – Ability to avoid violent reaction due to external stimuli

*Reproduced from Rozumov 56th JPM
120mm M865 & M1002 Tank Training Rounds

• Electrically initiated through multi-step ignition train
• Main energetic fill of igniter is benite
• Requirements:
  • Propellant must function at extreme temperatures
    • Hot: 145°F
    • Cold: -46°F
  • No changes to current ballistic firing tables
  • Compatibility with all current energetics
  • Must meet current ignition times
Objective

• Evaluate current DSSP formulations in 120mm tank igniters
  • Multiple formulations available for demonstration
  • Down selecting best suited formulation and optimizing to meet ARDEC requirements
• Design electrodes to optimize ignition
  • Can control where and when propellant ignites
• Improve understanding of propellant reaction mechanism
  • How and why does it burn?
  • What can be done to improve how it burns?
**HIPEP**
- Non metalized high performance propellant
- Flame insensitive
- Reactions stops with removal of electrical power
- Burn Rate: Tailorable, from 0.5 to > 10ips*, 0.4 < η < 0.9

**BADB**
- Metalized propellant (Boron)
- Flame sensitive
- Lower flame temperature
- Continues to burn once ignited
- Burn Rate: Tailorable, from 0.4 to >15ips*, 0.4 < η < 0.9

**Compatibilities**
- Incompatible with many metals (Iron, Nickel, Copper, etc.)
- Compatible with common polymers (Conventional engineering plastics)

* Cured strand burning rates, 1000psi
Design Considerations – Electrode Configuration

FIVE ELECTRODE CONCEPT

Four – Outer Electrodes
One – Inner Electrode

- Stainless steel electrodes
- Ignition at cathode or anode

Cathode

Anode
Proof of Concept Testing

First prototype - Stainless steel simulated igniter tube

- Performed at DSSP
- Two propellant candidates
  - HIPEP
  - BADD
- Test voltage – 300V
- Single electrical pulse

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Proof of Concept Testing

Success!

- Perforations on polyethylene liner in alignment with igniter tube holes
  - All holes opened – Current system does not see consistent burn through all igniter holes
  - Polyethylene tube part of igniter enhancement effort separately supported by PM MAS due to issues with current purple lacquer
- Some propellant unconsumed
  - Phase II will look at what quantity of material is actually required – current firing maximized all available space in the primer tube
- Electrodes were twisted and broken – design optimization work still needed
Ignition

**HIPEP Propellant**

*Stills are in 172µs intervals*

- Additional tests performed at DSSP with high speed camera
- Sequential ignition along primer body
- Total action time* = 24.6ms
- Igniter perforations open after ~ 1ms

*Total action time is defined as the time from observed smoke to dissipation of flames*
**BADB Propellant**

- Uneven ignition - igniter holes skipped as reaction spreads
- Intense fireball generated
- Lower power requirement than HIPEP
- Total action time* = 19.5ms

*Total action time is defined as the time from observed smoke to dissipation of flames*

Stills are in 173µs - 316µs intervals
## UN Series 3 Tests – Classification for New Substances

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Igniter Sensitivity</th>
<th>Impact ERL (cm)</th>
<th>Friction (GO / No GO) (N)</th>
<th>ESD (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIPEP</td>
<td></td>
<td>&gt;158.5</td>
<td>No GO</td>
<td>&gt;0.25</td>
</tr>
<tr>
<td>BADB</td>
<td></td>
<td>&gt;158.5</td>
<td>No GO</td>
<td>&gt;0.25</td>
</tr>
<tr>
<td>Class 3 PETN</td>
<td></td>
<td>18.8</td>
<td>288 / 252</td>
<td>&gt;0.25</td>
</tr>
<tr>
<td>Class 1 Type 2 RDX</td>
<td></td>
<td>23.2</td>
<td>&gt;360</td>
<td>&gt;0.25</td>
</tr>
</tbody>
</table>

Both ECEM formulations did not react at under the maximum loads for impact, friction, and ESD tests.
**Thermal Stability**

**Uninstrumented Thermal Stability**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Weight Loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIPEP</td>
<td>&gt;1.00</td>
</tr>
<tr>
<td>BADB</td>
<td>&gt;1.00</td>
</tr>
<tr>
<td>Propellant, Passing</td>
<td>&lt;1.00</td>
</tr>
</tbody>
</table>

- Possible moisture problem – propellants are hygroscopic
- Follow on testing to be performed
  - Instrumented thermal stability (mass spec)
- Discovered formulation and processing issue at ARDEC

Cut up pre-test samples

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Future Work

• Investigate ingredients and alternative formulations to improve performance, moisture absorption and stability at hot and cold temperatures

• Conduct static igniter firing tests to collect pressure data at the primer holes

• Evaluate the propellants in a ballistic simulator
  • Will give insight as to whether or not enough hot particles are being generated to light a bed of propellant in 120mm tank rounds

• Start adapting this technology for explosives and thrusters applications
Summary

• Completed safety and proof of concept testing
• Optimize
  • Propellant formulation
  • Electrode design
  • Mass of propellant
• Test performance in a ballistic simulator
• Adapt technology for other energetic applications
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• Alma Valdivia
• Tim Manship
Questions?
Back Up Slides
Electrode Designs

- **Two Electrodes**
- **Four Electrodes (aligned)**
- **Four Electrodes (unaligned)**
- **Mylar Foil**

**Side View**

**Top View**
Bad Propellant
Thermal Stability Update

Thermal Stability Update - HIPEP

• New material tested at DSSP
• Samples made with stoichiometric HAN slumped at 75°C, weight loss noted
• Sample weight reverted back to original value under ambient conditions

Initial Formulation Problems
• Stabilized HAN was found to contain excess hydroxylamine
• Hydroxylamine decomposes at 58°C
BADB Propellant