Novel Manufacturing Process Development and Evaluation of the High Blast Explosive PAX-3 with BDNP A/F and R8002 Plasticizers

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Enhanced Blast Explosives

- Deliver More Energy on Target than Traditional Explosives

- Types of Enhanced Blast Explosives
  - Metallized Explosives
  - Reactive Surround
  - Fuel Air
  - Thermobaric

Fig. Comparison of conventional explosives and enhanced explosives.
Enhanced Blast Explosives

- Rely on Blast (Primary) and Heat (Secondary) for their Effects
- Effects Intensified in Confined Spaces (Buildings, Bunkers, Caves, Vehicles, etc.)
- Active Elements are an Explosive and a Fuel (metal)
- Vacuum or Oxygen Depletion Effect is Achieved
PAX-3

• Developed by ARDEC Under the Novel Energetics Science and Technology Objective (STO)
• Evaluation for the M141 Bunker Defeat Munition
• Evaluation for Line of Sight Multi-Purpose (LOS-MP)
PAX-3

- PAX-3
  - HMX
  - Cellulose Acetate Butyrate (CAB)
  - BDNPA/F plasticizer
  - Aluminum
- Replacement for Aluminized Comp. A-3

Concrete wall 10’ wide, 10’ tall 8” thick, reinforced with double steel rebar
# PAX-3 INSENSITIVE MUNITION TESTING

## PAX-3 3.2” Generic Shaped Charge IM Test Summary

<table>
<thead>
<tr>
<th>IM Test</th>
<th># of Tests</th>
<th>Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bullet Impact (50 cal 2800 ft/s)</td>
<td>2</td>
<td>Pass No Reaction</td>
</tr>
<tr>
<td>Army Fragment Impact (Cube 6000 ft/s)</td>
<td>2</td>
<td>Pass Burn</td>
</tr>
<tr>
<td>Slow Cook Off (50 F /hr)</td>
<td>2</td>
<td>Fail Explosion/Deflagration**</td>
</tr>
<tr>
<td>Fast Cook Off</td>
<td>2</td>
<td>Pass Burn</td>
</tr>
</tbody>
</table>

* Initial Assessment

** This reaction can be potentially mitigated by adequately venting the warhead

## PAX-3 SENSITIVITY AND PERFORMANCE TEST DATA

<table>
<thead>
<tr>
<th></th>
<th>PAX-3</th>
<th>Al Comp A3</th>
<th>LX-14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact (cm)(50%)</td>
<td>39.5</td>
<td>80.4</td>
<td>26</td>
</tr>
<tr>
<td>LSGT (50%)</td>
<td>129.5</td>
<td>119+/- 3</td>
<td>199</td>
</tr>
<tr>
<td>Detonation Velocity (m/sec)</td>
<td>8070</td>
<td>8199</td>
<td>8680</td>
</tr>
</tbody>
</table>

* Performance and sensitivity data provided by ARDEC

Data Originally Presented at 2006 IMEM
PAX-3 Current Processing

- **HSAAP Slurry Processing**
  - Explosive intermediates slurried in water
  - Polymer / Plasticizer dispersed in solvent
  - Coating / processing cycle
  - Recovery / reuse of solvent

- **Traditional Method Incompatible with Thermobaric PBX**
  - Aluminum powder readily oxidized by water
  - Safety issues significant at production-scale operations

- **“Water Replacement” (WR) Fluid Evaluated** *
  - Not reactive with metal powders
  - Fluidizing effect of water
  - Colorless, nonflammable liquid
  - Similar boiling point range as water
  - Recovery of WR Fluid Key to Controlling Product Cost

* Previously Reported in 2006 IMEM
PAX-3 Current Processing

• **Issues**
  • Water Replacement Fluid Expensive
  • Separation of Water Replacement Fluid from Solvent Difficult
  • Supplier Discontinued “WR” Fluid Currently Employed for Manufacture

• **New Solution**
  • Re-evaluate Traditional Aqueous Slurry Technology to Manufacture PAX-3
  • Known Technology
  • Minor Changes to Processing Technique
  • Significant Cost Savings to the Customer
PAX-3 Aqueous Development

• Processing Concerns
  • Hydrogen Gas Generation During Coating Cycle
    • Time / Temperature of Aluminum Exposure in Slurry
    • pH of the Slurry Medium

• Material Evaluation
  • Explore any “Additives” that has the Potential to Impede or Delay Gas Generation
PAX-3 Aqueous Process Development

- Lab-Scale Process Development
  - Design of Experiments
    - Baseline Using “WR” Parameters
  - Systematic Evaluation of Process Parameters for PAX-3
    - Time
    - Temperature
    - Agitation
    - Addition Rates
    - Process “Additives”
  - Typical lab batch size of 1,000 grams
  - 2 “Additives” Identified and Employed for Processing
    - Gas Generation Monitored Real Time
      - H2 Scan: HY-Optima 1720 Process Monitor
PAX-3 Laboratory Granulation

Granulation Data PAX-3

% Undersize (Cumulative) vs. Particle Size (μm)
Process Development Conclusion

- **Key Variables**
  - **Time**
    - Resonance Time – Coating Process
  - **Solvent Concentration**
    - Very Tight Tolerance
      - No Growth of Granules
      - Excessive, Rapid Growth into Agglomerations-Undesired Product
- **Hydrogen Gas**
  - Negligible Level Detected at Lab Scale Evaluation
- **Production Scale Batch**
  - FMEA Completed
  - Industrial Hydrogen Gas Detector Purchased/Commissioned
  - Process Parameters Established Based on Lab Scale Development Efforts
  - 2 x 500 lb Batches Scheduled for Week of April 27th
Plasticizers

- **BDNP A/F**
  - Energetic Plasticizer
    - 50% bis(2,2-dinitropropyl)acetal (BDNPA)
    - 50% bis(2,2-dinitropropyl) formal (BDNPF)
  - Initially Developed in 1950’s for Polaris Program
  - First Manufactured by U.S. Navy (Indian Head) and Aerojet in the 1960’s
  - Later Manufactured by Thiokol in the 1990’s
  - Used Today in Various Formulations
    - LOVA Propellants
    - Navy PBX 106 Formulation
    - IM Explosives (PBXN-106, PAX-2A and PAX-3)

- **R8002**
  - 50% Dinitroethylbenzene (DNEB)
  - 50% Trinitroethylbenzene (TNEB)
  - Similar to K10 (65:35 DNEB:TNEB)
  - Used Internationally as an Energetic Plasticizer in Experimental Applications
PAX-3 w/ R8002

• Processing
  • Drop in Replacement with Current Aqueous Procedure
  • No Observable Change in Processing Steps

• Observations
  • Binder Lacquer system is less viscous than BDNP A/F
  • Binder Components Readily Mix with Little Mechanical Input
  • PAX-3 Product Using R8002 Generates a Higher Bulk Density Under Same Process Conditions
  • No Compatibility Issues
DSC Analysis

Plasticizers
BDNP A/F vs. R8002
Ramp 5°C/min

PAX-3
BDNP A/F vs. R8002
Ramp 5°C/min
# PAX-3 Analysis

<table>
<thead>
<tr>
<th>Batch #</th>
<th>PAX-3 Plasticizer</th>
<th>DSC Exothermic Peak °C</th>
<th>VTS Evolved Gas g/cc</th>
<th>Press Density g/ml</th>
<th>ERL Impact cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1069-88C</td>
<td>BDPN A/F</td>
<td>275.34</td>
<td>0.266</td>
<td>1.73</td>
<td>36.14</td>
</tr>
<tr>
<td>1069-114</td>
<td>R8002</td>
<td>274.69</td>
<td>0.132</td>
<td>1.80</td>
<td>41.40</td>
</tr>
</tbody>
</table>
Conclusion

• The Aqueous Coating Method Provides Spec. Product
• Method Conforms to HSAAP Infrastructure
  • No Specialized Pumps, Seal, or Handling Equipment as with “WR” Method
• Product to Be Scaled to 500 lb Batch Size for Pilot Production Trial
• The R8002 Plasticizer Showed No Processing or Compatibility Concerns
  • Drop in Replacement for BDNPA/F
IT ALL STARTS HERE!!