Manufacturing of PAX-3 High Explosive

Presented to:
NDIA IMEM 2018
April 2018
• PAX-3 is a high blast explosive with metal pushing capabilities
• Developed to replace Aluminized Comp-A3
• Used in pressed applications for warheads
• Molding powder composed of
  – HMX
  – Aluminum
  – BDNPA/F
  – CAB
• Looking to requalify PAX-3 manufactured under a new process
• Formulation & constituents remain the same
• Back in 2000’s the method of Twin Screw Extrusion (TSE) was evaluated as a manufacturing process for PAX-3
• TSE is a 2-step continuous mixing process
• It utilizes high shear mixing through a screw machine
• Components added to feed stock that extrude the final produce through an orifice
• ARDEC had studied mixing compositions and flexibility for the process to control
• The TSE process was as a manufacturing method in which ARDEC qualified the process back in 2015
• A 19mm Die TSE located at Milan was used to produce over 2000lb using
  – Feed material was a non-aluminized analogous formulation & Aluminum in a performance fluid
• BAE has scaled up manufacturing of PAX-3 at Holston
  – 500 gallon batch scale
  – Uses water solution

• Single step process where HMX & Aluminum is coated with binder/laquer

• Manufactured over 2000lbs to date
PROCESS CHANGE

• Changes in processing could lead to variation in final product
  – Residual solvents/water
  – Achieving correct % of constituents
  – Foreign materials added during the process
  – Source materials or replacement ingredients

• Potential impact on changes in material?
  – safety & handling
  – loading conditions
  – performance degradation
  – aging concerns
DoD Energetic Materials Qualification Process Test Protocol:


3. DoD Energetics Qualification Program Matrix for Main Charge Explosives.
QUALIFICATION TESTING

- **Thermal Stability & Compatibility**
  - VTS
  - Thermal Stability
  - DSC
  - VTS Generic Material Testing
  - TGA
  - Woods Metal Bath (5-sec explosion temperature)
  - Critical Temperature Calculation
  - Variable Confinement Cook-off Test (fast and slow)
  - Small scale burn

- **Sensitivity**
  - Small Scale ESD
  - ERL/Bruceton Impact
  - BAM Friction
  - LSGT Shock Sensitivity
  - Cap Sensitivity
  - Setback

- **Chemical/Physical/Mechanical Properties**
  - Coefficient of Thermal Expansion
  - Comprehensive Strength
  - Density/Bulk Density
  - Irreversible Growth
  - Exudation

- **Aging**
  - Safe shelf Life
  - Sensitivity Tests
  - Mechanical Properties (on un-aged and aged material)

- **Toxicity Evaluation**
  - Products of Combustion/Detonation
  - Toxicity Clearance Report

- **Performance Properties**
  - Detonation Velocity/Detonation Pressure
  - Critical Diameter
MOLDING POWDER

HMX Class 1

HMX Class 5

PAX-3 Slurry material under different magnification
### STABILITY CHARACTERIZATION

<table>
<thead>
<tr>
<th>TEST TITLE</th>
<th>TESTMETHOD</th>
<th>TEST CONDITION</th>
<th>TEST RANGE OR LIMIT</th>
<th>TEST RESULT (SLURRY PAX-3)</th>
<th>REFERENCE (EXTRUDED PAX-3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 STABILITY CHARACTERIZATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1.1 Vacuum Thermal Stability (VTS or MVTS)</td>
<td>AOP-7 202.01.001</td>
<td>5.00±0.01g 100 °C/48 h Or 100 °C/40 h</td>
<td>≤ 2 ml/g of gas evolved (100 °C/40 h)</td>
<td>0.0660 ml/g</td>
<td>0.0740 ml/g</td>
</tr>
<tr>
<td>1.2 Thermal Stability at +75 °C</td>
<td>TB 700-2 UN Test 3c</td>
<td>50g 75 °C/48 h Evidence of Self Heating</td>
<td>Start 49.9700g Final 49.9219g (0.10% change) No evidence of instability</td>
<td>Start 49.4041g Final 49.3558g (0.10% change) No evidence of instability</td>
<td></td>
</tr>
</tbody>
</table>
• Vacuum Thermal Stability (VTS) Test
  – 5g sample held at 100°C for 40hrs
  – Gas evolved 0.066 ml/g (0.074ml/g ref)
  – Pass, criteria – explosives will no exceed 2ml/g

• Thermal Stability
  – 50g sample held at 75°C for 100hrs
  – Result - no indication of reaction (mass loss, color change)
- DSC Testing
  - Heating rate of 5°C/min
  - Thermal run away event

- PAX-3 Slurry
  - Onset 277.43°C
  - Peak 279.2°C

- PAX-3 Reference
  - Onset 275.39°C
  - Peak 277.07°C
• TGA Results
  – Onset Temp – 262°C (Slurry), 258°C (Reference)
  – Reaction – approx. 80% of material reacted
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<tbody>
<tr>
<td>4</td>
<td>Sensitivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.1 Electrostatic Discharge (ESD)</td>
<td></td>
<td></td>
<td>0/20 at 0.0063J (No-Go)</td>
<td>0/20 at 0.25J (No-Go)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>0.009J (Go)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.2 ERL/Bruceton Impact</td>
<td></td>
<td></td>
<td>24.6cm (50%)</td>
<td>42.1cm (50%)</td>
<td></td>
</tr>
<tr>
<td>4.3 BAM Friction</td>
<td></td>
<td></td>
<td>0/10 at 288N (No-Go)</td>
<td>0/10 at 288N (No-Go)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>324N (Go)</td>
<td>324N (Go)</td>
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<tr>
<td>4.4 ABL Friction</td>
<td></td>
<td></td>
<td>0/20N at 578N (No-Go)</td>
<td>no data</td>
<td>no data</td>
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<tr>
<td></td>
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<td></td>
<td>800N (Go)</td>
<td></td>
<td></td>
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<tr>
<td>4.5 LSGT Shock Sensitivity</td>
<td></td>
<td></td>
<td>155 Cards</td>
<td>143 Cards</td>
<td></td>
</tr>
<tr>
<td>4.6 Cap Sensetivity</td>
<td></td>
<td></td>
<td>fail</td>
<td>fail</td>
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</tbody>
</table>

- ESD Tests were conducted on the new device for Slurry PAX-3 and old device for extruded PAX-3. All other materials appear more ESD sensitive when run on the new equipment.
- Drop height for impact does appear to have a lower 50% point. This is still in the range of secondary explosives.
- ABL Friction was never conducted on Extruded PAX-3.
• Large Scale Gap Test (LSGT)
  – 50% point for shock sensitivity
  – Pentolite donor pellets
  – PMMA gap to PAX-3 acceptor

• Slurry Process
  – 155 Cards (36.8kbar)

• TSE Process
  – 143 Cards (43.4kbar)
MECHANICAL PROPERTIES

- **Uniaxial Compression**
  - 1.5” x .75” cylinders
  - Strain Rate = 0.01/s
- **Similar behavior under loading**
  - Peak Compressive Stress
    - 2848 PSI (Slurry)
    - 3002 PSI (TSE)
  - Modulus
    - 67,400 PSI (Slurry)
    - 51,200 PSI (TSE)
SUMMARY

• Initial testing shows no signs of concern based on results
  – Particles appear to be well coated
  – Similar characteristics & response
    • Thermal
    • Sensitivity
    • Physical
  – Awaiting Aged sample results
  – Composition Analysis shows no foreign materials
  – PAX-3 Slurry should maintain similar performance
• Currently PAX-3 is of interest to be used in tank ammo and grenade applications

• Testing to investigate material response when subject to setback is being conducted at Indian Head
  – Explosive samples are subject to accelerating loading to evaluate defect sizes and response
Questions?