Always a Step Ahead

ARDEC

ARMAMENTS

Manufacturing of PAX-3 High Explosive

Presented to:

NDIA IMEM 2018

April 2018

UNPARALLELED

COMMITMENT

& SOLUTIONS

Act like someone's life depends on what we do.

U.S. ARMY

U.S. ARMY RDECOM®

U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT & ENGINEERING CENTER

BACKGROUND

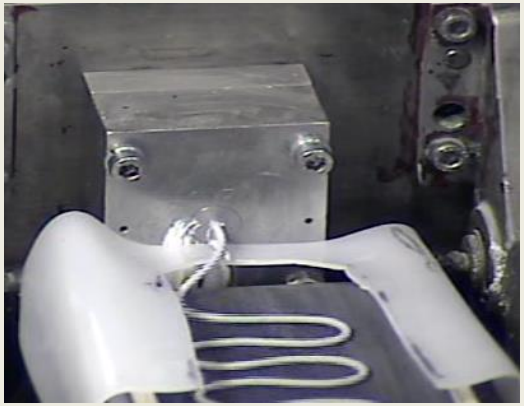
- PAX-3 is a high blast explosive with metal pushing capabilities
- Developed to replace Aluminized Comp-A3
- Used in pressed applications for warheads
- Molding powder composed of
  - HMX
  - Aluminum
  - BDNPA/F
  - CAB
- Looking to requalify PAX-3 manufactured under a new process
- Formulation & constituents remain the same

TWIN SCREW EXTRUSION

- 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

PAX-3 QUALIFICATION

- 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



Extrusion

Granulation

Molding Powder (Final Product)

PAX-3 SLURRY PROCESS

- 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

Molding Powder (final product)

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

EXPLOSIVE QUALIFICATION

- **DoD Energetic Materials Qualification Process Test Protocol:**

(1) Allied Ordnance Publication Seven (AOP-7) (Edition 2 Rev. 3), "Manual of Data Requirements and Tests for the Qualification of Explosive Materials for Military Use", December 2007

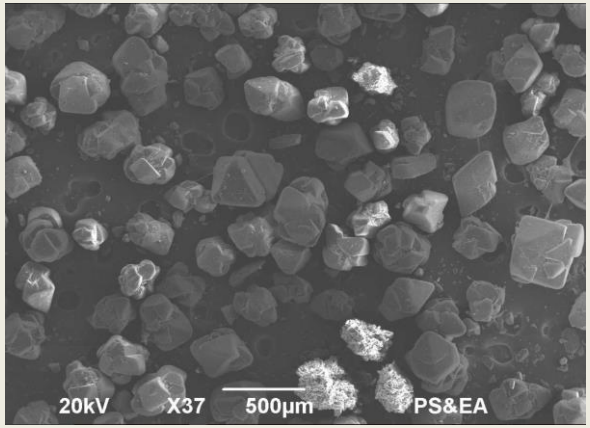
(2) Standardization Agreement (STANAG) 4170 (Edition 3), "Principles and Methodology for the Qualification of Explosive Materials for Military Use", 2007.

(3) DoD Energetics Qualification Program Matrix for Main Charge Explosives

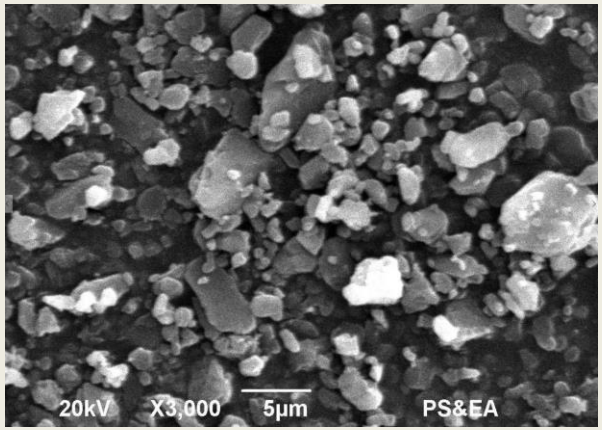
QUALIFICATION TESTING

- 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

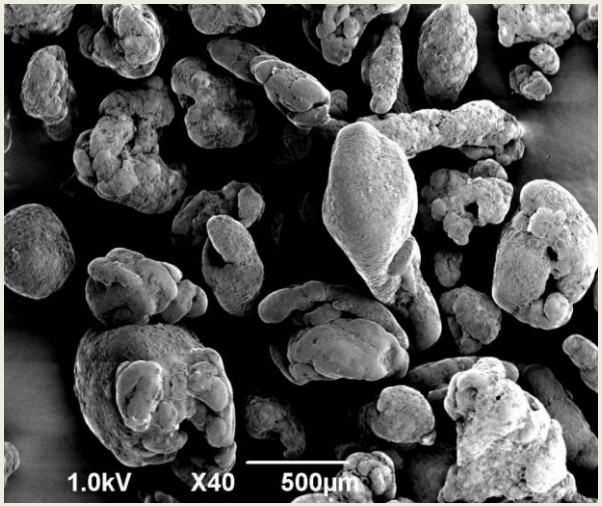
MOLDING POWDER

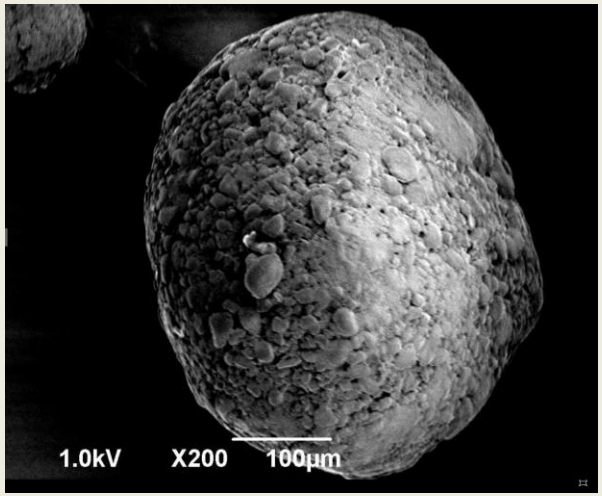


HMX Class 1



HMX Class 5





PAX-3 Slurry material under different magnification

STABILITY CHARACTERIZATION

	TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT (SLURRY PAX-3)	REFERENCE (EXTRUDED PAX-3)
1	**STABILITY CHARACTERIZATION**					
1.1	Vacuum Thermal Stability (VTS or MVTS)	AOP-7	5.00±0.01g	≤ 2 ml/g of gas evolved	0.0660 ml/g	0.0740 ml/g
		202.01.001	100 °C/48 h	(100 °C/40 h)		
			Or			
			100 °C/40 h			
1.2	Thermal Stability at +75 °C	TB 700-2	50g	Evidence of Self Heating	Start 49.9700g	Start 49.4041g
		UN Test 3c	75 °C/48 h		Final 49.9219g	Final 49.3558g
					(0.10% chage)	(0.10% chage)
					No evidence of instability	No evidence of instability

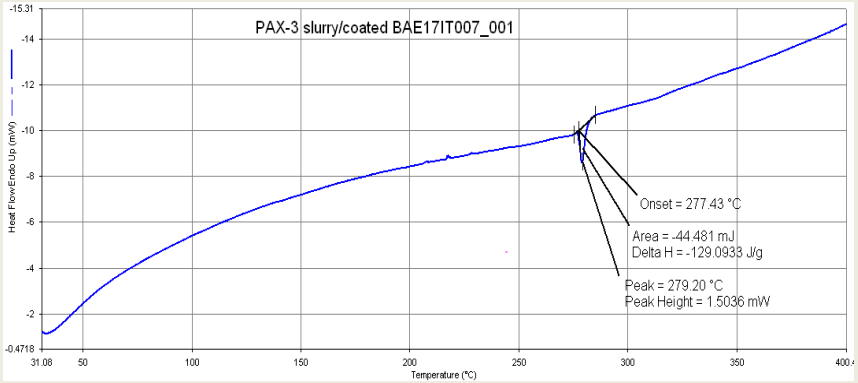
STABILITY CHARACTERIZATION

- 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

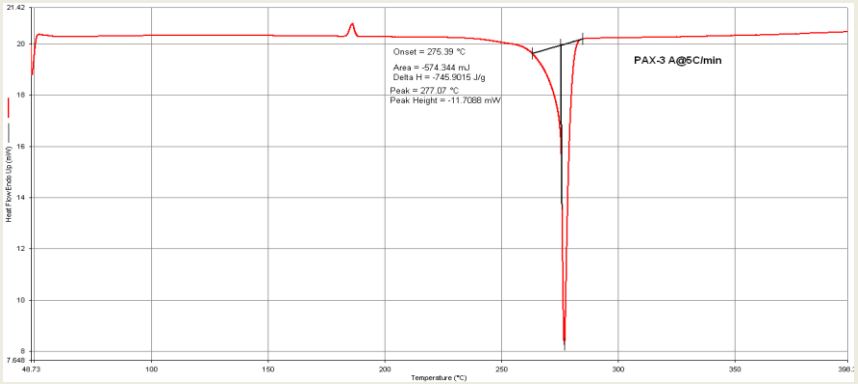
- Thermal Stability
  - 50g sample held at 75°C for 100hrs
  - Result - no indication of reaction (mass loss, color change)

THERMAL CHARACTERIZATION

- 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

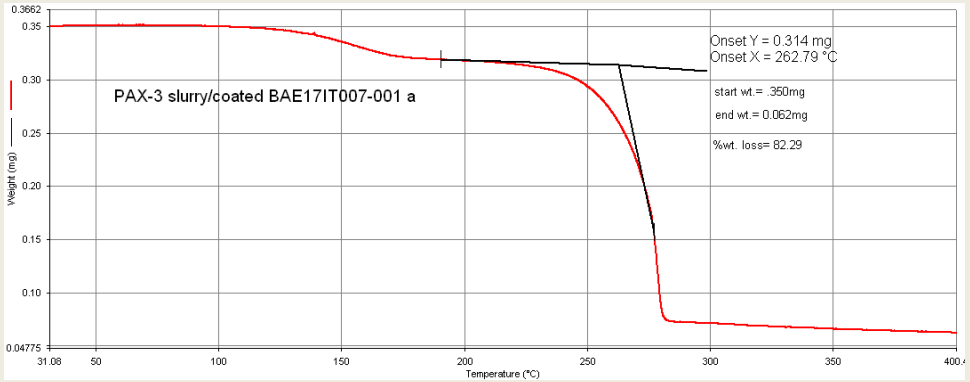


PAX-3 Slurry



PAX-3 Reference

TGA Plots



- TGA Results
  - Onset Temp – 262°C (Slurry), 258°C (Reference)
  - Reaction – approx. 80% of material reacted

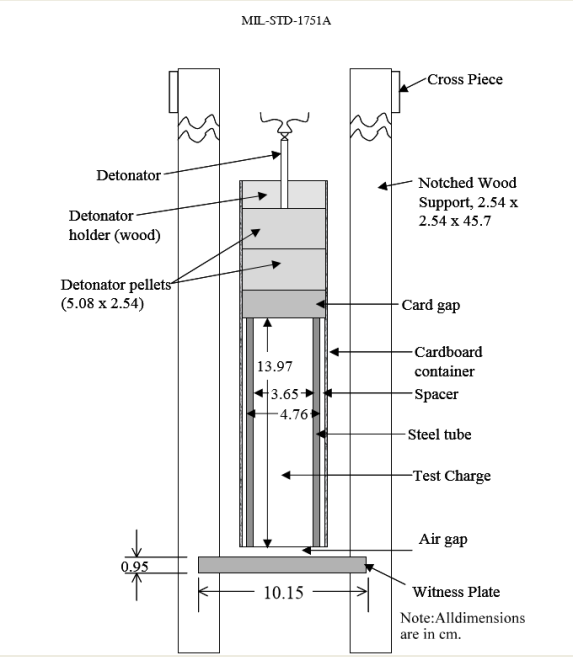
SENSETIVITY RESULTS

	TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT (SLURRY PAX-3)	REFERENCE (EXTRUDED PAX-3)
4	Sensitivity					
4.1	Electrostatic Discharge (ESD)				0/20 at 0.0063J (No-Go) 0.009J (Go)	0/20 at 0.25J (No-Go)
4.2	ERL/Bruceton Impact				24.6cm (50%)	42.1cm (50%)
4.3	BAM Friction				0/10 at 288N (No-Go) 324N (Go)	0/10 at 288N (No-Go) 324N (Go)
4.4	ABL Friction				0/20N at 578N (No-Go) 800N (Go)	no data no data
4.5	LSGT Shock Sensitivity				155 Cards	143 Cards
4.6	Cap Sensetivity				fail	fail

- **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**

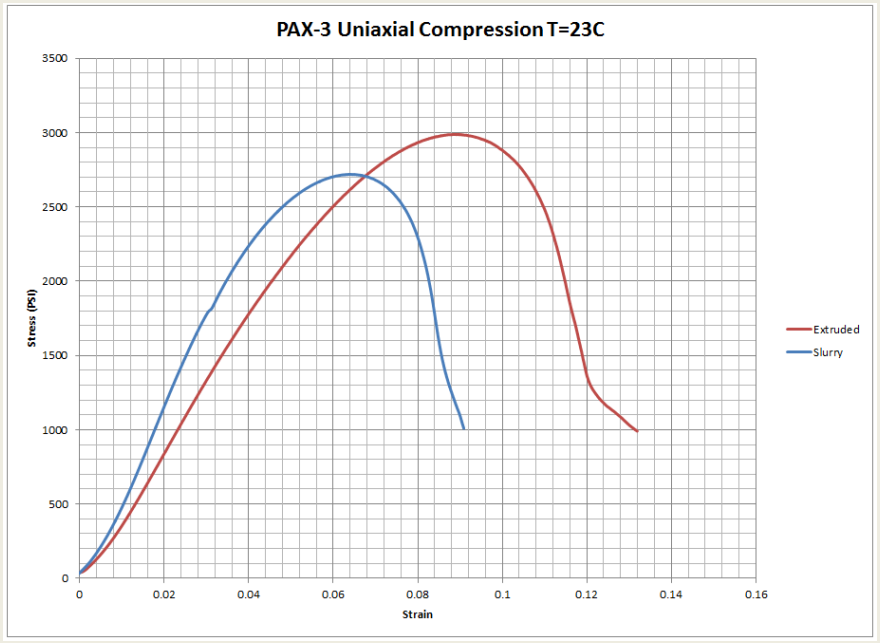
SHOCK SENESTIVITY

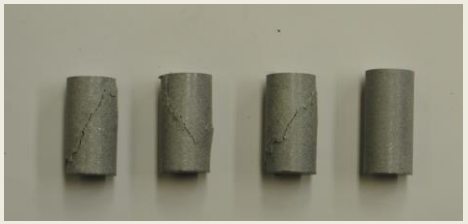
- Large Scale Gap Test (LSGT)
  - 50% point for shock sensitivity
  - Pentolite donor pellets
  - PMMA gap to PAX-3 acceptor
- Slurry Process
  - 155 Cards (36.8kbar)
- TSE Process
  - 143 Cards (43.4kbar)



MECHANICAL PROPERTIES

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

ADDITIONAL

- 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

THE END

Questions?