U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – ARMAMENTS CENTER

Evaluation of PBXN-9 Utilizing FEM HMX

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DISTRIBUTION A

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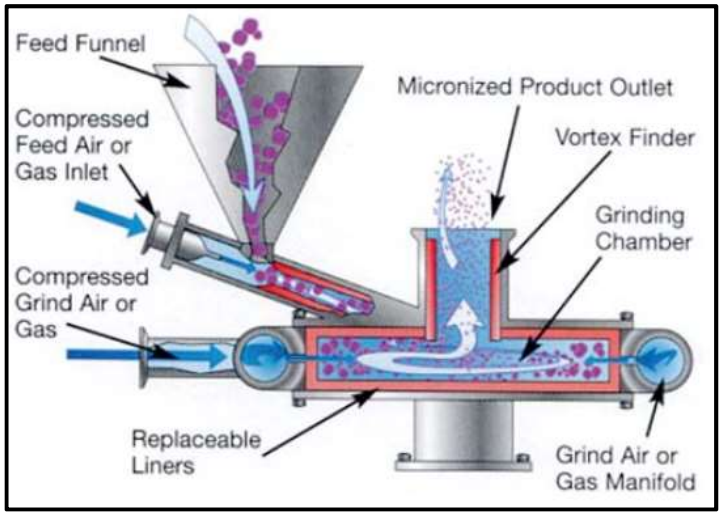
BRIEFING OUTLINE

1. Background & Technical Description
2. PBXN-9 FEM HMX Characterization & Pressing
3. Testing and Evaluation
    a) Performance Testing
    b) Shock Sensitivity Testing
    c) Mechanical Properties Testing
    d) Small-Scale Fragment Attack Testing
    e) Setback Survivability Testing
    f) Irreversible Growth Study
    g) Exudation Study
4. Conclusions

BACKGROUND & TECHNICAL DESCRIPTION

- PBXN-9 Formulation:
  - HMX
  - DOA (dioctyl adipate) as plasticizer
  - HyTemp as binder
- Fluid Energy Mill (FEM) Technology:
  - Utilizes compressed air to grind particles to less than 10 microns in size
- FEM nitramines are currently used in qualified energetic formulations:
  - Properties have not yet been fully characterized
  - FEM RDX is currently in full rate production, however, FEM HMX has not been fully explored



- BAE Systems has produced FEM HMX formulations:
  - LX-14 with 80% and 100% FEM HMX
  - PBXN-9 with 100% FEM HMX
  - Formulations have been successfully scaled-up for LSGT and performance testing

https://bulkhand.com/2014/08/sturtevant-proven-size-reduction-classifying-technology/
http://www.jbmprispac.com/pd/15/air-jet-mill

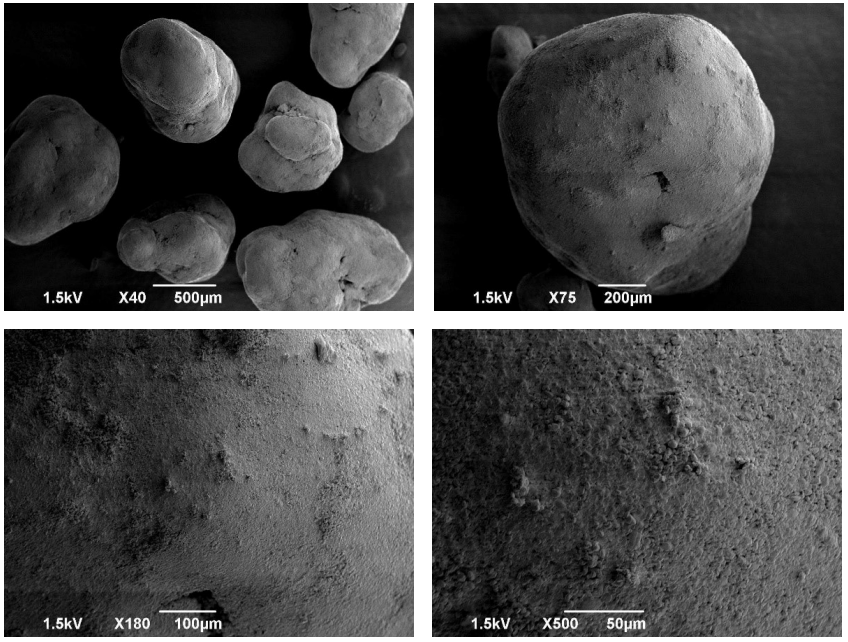
PBXN-9 FEM HMX: CHARACTERIZATION

➢ Initial Safety Testing:

Material	ERL Impact (cm)	BAM Friction (N)	ESD (J)
PBXN-9 FEM HMX	27.7	10/10 No Goes @ 216	20/20 No Goes @ 0.020
Legacy PBXN-9	40.9	10/10 No Goes @ 324	20/20 No Goes @ 0.020
RDX (Class I Type II)	27.2	10/10 No Goes @ 168	20/20 No Goes @ 0.040

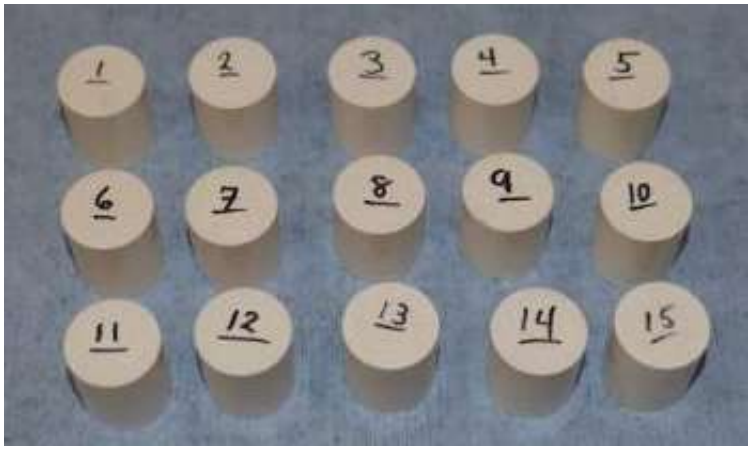
➢ SEM Images of Molding Powder:

- ✓ Granules were well coated and spherical in shape



➢ Pressing Study:

- ✓ Consistently achieved 98.5% theoretical maximum density (TMD)



PBXN-9 FEM HMX: LARGE SCALE DETONATION VELOCITY TEST

- A Large Scale Detonation Velocity (LSDV) test was conduct to determine the detonation velocity of PBXN-9 FEM HMX compared to legacy PBXN-9
  - ✓ **Result = PBXN-9 FEM HMX detonation velocity is equivalent to legacy PBXN-9**

Formulation	Density (g/cc)	DV (km/s)	Dent (inches)
PBXN-9 with 100% FEM HMX	1.72	8.41	0.382
PBXN-9 with 100% FEM HMX	1.72	8.40	0.369
Legacy PBXN-9	1.64	8.07	0.378
Legacy PBXN-9	1.64	8.11	0.376
Legacy PBXN-9	1.70	8.33	0.400
Legacy PBXN-9	1.70	8.30	0.403
Legacy PBXN-9	1.74	8.46	0.417
Legacy PBXN-9	1.74	8.48	0.426

PBXN-9 FEM HMX: LARGE SCALE GAP TEST

- A Large Scale Gap Test (LSGT) was conduct to determine the shock sensitivity of PBXN-9 FEM HMX compared to legacy PBXN-9
  - ✓ **Result = PBXN-9 FEM HMX showed a 37 – 54 card improvement compared to legacy PBXN-9**

Formulation	Testing Facility	Percent of FEM HMX	LSGT (Cards)	LSGT (Kbar)	Density (g/cc)
PBXN-9 FEM HMX	Picatinny Arsenal	100	167.5	30.70	1.72
Legacy PBXN-9	Picatinny Arsenal	0	222.0	16.47	1.70
Legacy PBXN-9	Picatinny Arsenal	0	205.0	19.54	1.74
Legacy PBXN-9	BAE Systems	0	186.5	24.22	1.69
PBXN-9 FEM HMX	BAE Systems	45	184.5	24.81	1.67
PBXN-9 FEM HMX	BAE Systems	75	186.0	24.36	1.65
PBXN-9 FEM HMX	BAE Systems	100	156.0	35.69	1.65

PBXN-9 FEM HMX: UNI-AXIAL COMPRESSION TESTING

- A series of uni-axial compression tests were conduct at different temperatures to determine if utilizing 100% FEM HMX improved the mechanical strength of the PBXN-9 formulation
  - ✓ **Result = PBXN-9 FEM HMX showed an increase in strength, modulus, and strain at peak pressure compared to legacy PBXN-9**

PBXN-9 FEM HMX: SMALL-SCALE FRAGMENT ATTACK TEST

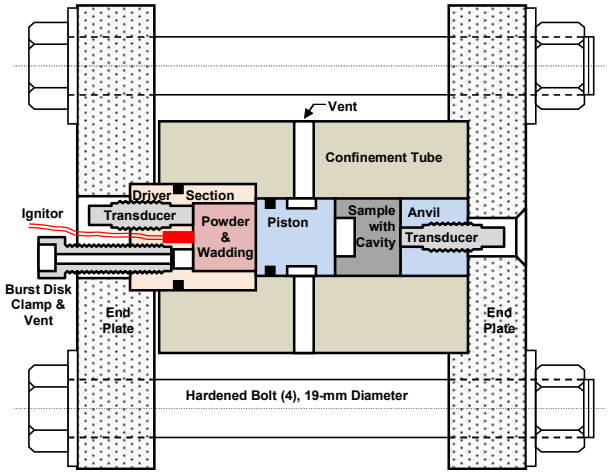
- Small-Scale Fragment Attack (SSFA) tests were conducted to determine the reaction violence from a frag attack on PBXN-9 FEM HMX compared to legacy PBXN-9
  - ✓ **Result = PBXN-9 FEM HMX had an improved response compared to legacy PBXN-9**

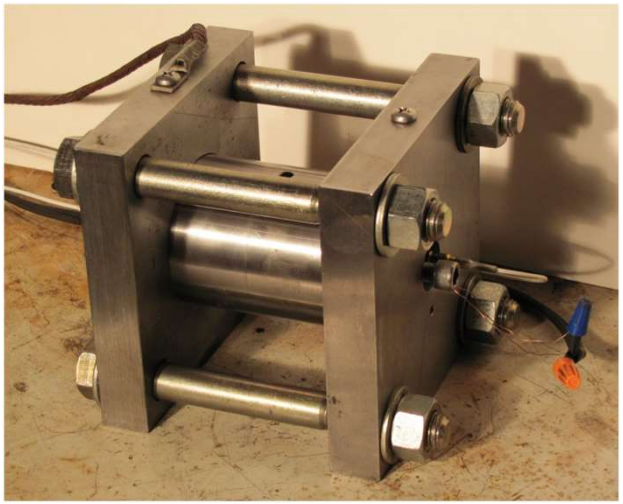
Sample	Results w.r.t. Cover Plate Thickness (inches) for Single Liner in RP-4			
	1/8" (3.2 mm)	1/4" (6.3 mm)	3/8" (9.5 mm)	1/2" (12.7 mm)
PBXN-9 FEM HMX	Detonation	No Reaction Nearly all HE remained No Reaction Nearly all HE remained	No Test	No Test
PBXN-9 (Legacy)	Detonation	Deflagration	No Reaction	No Test

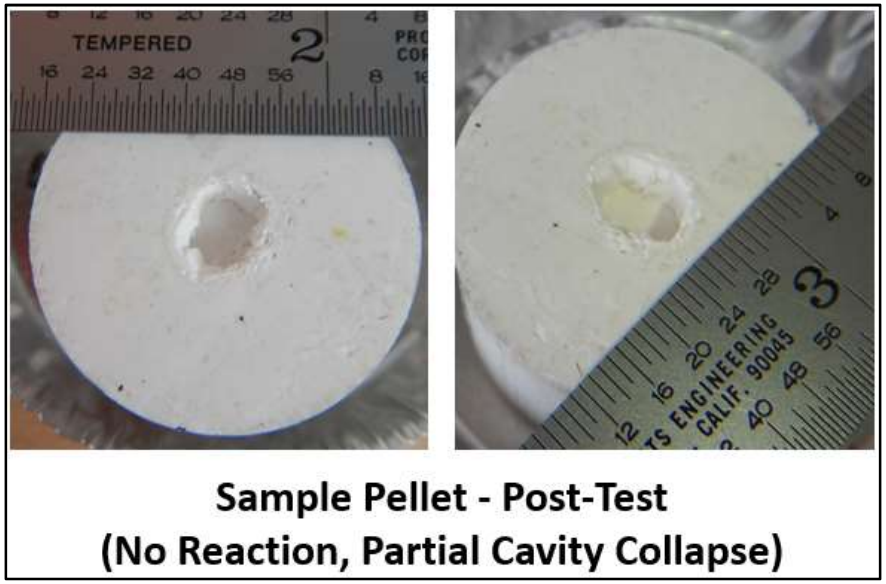
Levels of Reaction	
No Reaction	Apparatus intact with <1% tube expansion
Burn	Apparatus intact with tube bulged or having a single split; alternatively, rods broken with <1% tube expansion
Deflagration	End closures undamaged except for possible broken edges on Closure Plate; Tube split into pieces or split and opened wide, either which can break rods; Alternatively, tube just bulged and Cover Plate or rods broken to release pressure
Explosion	Clamp & Spacer broken, Cover Plate perforated but not sheared through opening in Clamp & Spacer, Tube split into pieces, Rods broken, Closure Plate broken with center intact
Detonation	Clamp & Spacer broken into pieces, Cover Plate sheared through opening in Clamp & Spacer, Tube and Closure Plate fragmented, no sample recovered

PBXN-9 FEM HMX: NSWC SETBACK RESULTS

- NSWC Setback testing was conducted on PBXN-9 FEM HMX as a screening tool for setback sensitivity
  - ✓ **Result = PBXN-9 FEM HMX showed improved response compared to legacy PBXN-9**





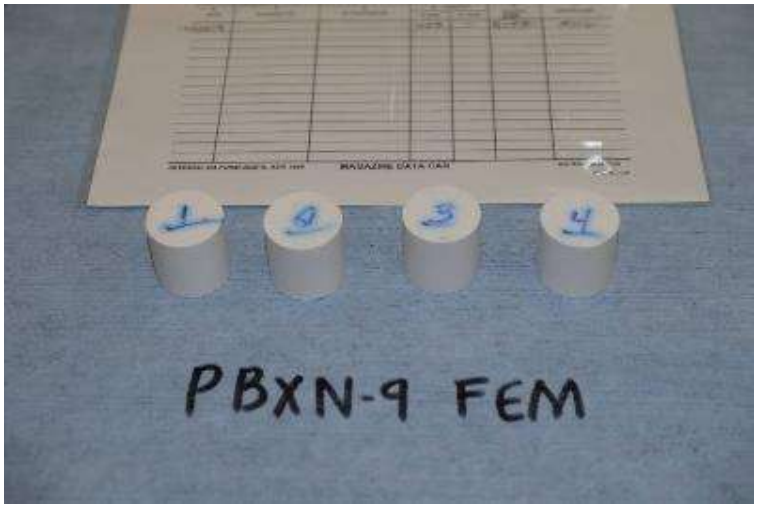


Sample Pellet - Post-Test
(No Reaction, Partial Cavity Collapse)

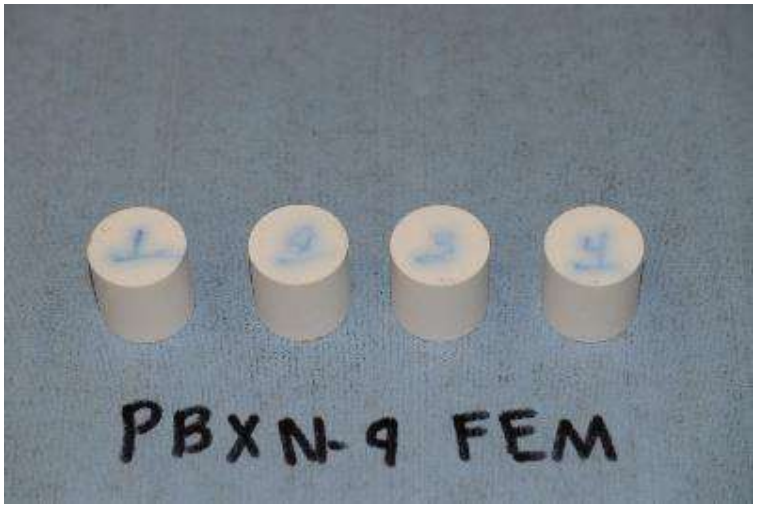
PBXN-9 FEM HMX: IRREVERSIBLE GROWTH STUDY

- Irreversible Growth testing was conducted to determine if PBXN-9 FEM HMX pellets increased in volume after thermal cycling
  - ✓ **Result = PBXN-9 FEM HEM showed no notable volume changes after thermal cycling; PASSED with no more than 1% volume change**

PBXN-9 FEM	Δ Volume (%)
1	-0.9565
2	-1.0258
3	-1.1548
4	-0.7295
Average	**-0.9666**



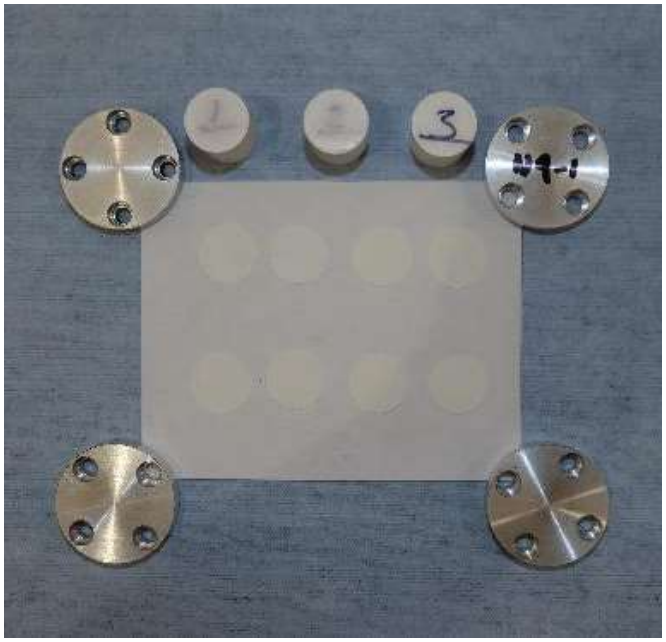
30 Temp Cycles
-54°C to 60°C
Dwell 4 hrs @ Extremes



PBXN-9 FEM HMX: EXUDATION STUDY

- Exudation testing was conducted to determine if the binder system exudates from pressed PBXN-9 FEM HMX after being exposed to elevated temperatures
  - ✓ **Result = PBXN-9 FEM HEM showed no evidence of exudation**

Test Cylinder	Sample Mass Loss (g)	% Exudation (Sample)	Filter Paper Mass Gain (g)	% Exudation (Filter Paper)
1	0.0411	0.0376	0.0161	0.0147
2	0.0238	0.0218	0.0169	0.0155
3	0.0357	0.0326	0.0240	0.0219



CONCLUSIONS

- ✓ A PBXN-9 analog utilizing Fluid Energy Milled (FEM) HMX was successfully developed, characterized, and evaluated as a collaborative effort between BAE Systems and DEVCOM AC

- ✓ The PBXN-9 FEM HMX formulation had equivalent performance compared to legacy PBXN-9
  - PBXN-9 FEM HMX: DV = 8.41 km/s (d = 1.72 g/cc)
  - Legacy PBXN-9: DV = 8.47 km/s (d = 1.74 g/cc)

- ✓ The PBXN-9 FEM HMX formulation had improved shock sensitivity, setback survivability, and mechanical properties compared to legacy PBXN-9:
  - LSGT testing resulted in 167.5 cards (legacy PBXN-9 LSGT = 205.0 to 222.0 cards)
  - Improved response in the SSFA test
  - Showed an improved response in the NSWC Setback Simulator test
  - Increase in strength, modulus, and strain at peak pressure

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QUESTIONS?