RDECOM

Meltable Explosives for Pressed Applications

ARMAMENT RESEARCH, DEVELOPMENT & ENGINEERING CENTER PICATINNY ARSENAL

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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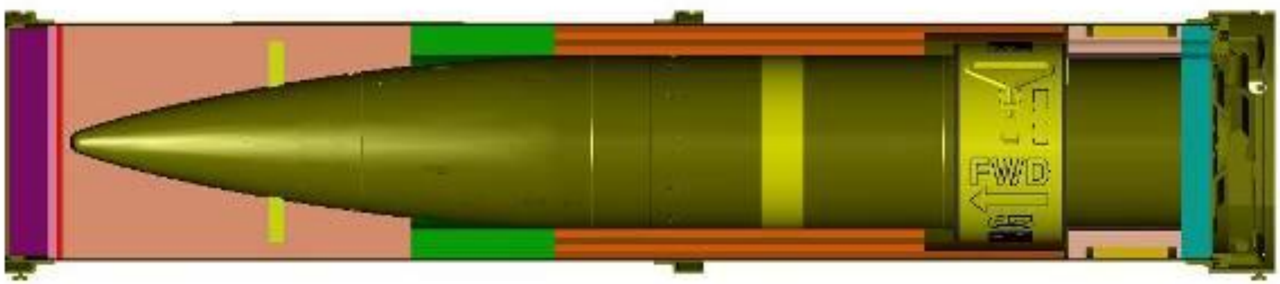
#13889

Overview

- Objectives
- Program Description
- Technology Description and Feasibility
- Characterization of Top Candidates
- Detonation Testing
- Final IM Testing
- Plan Forward
- Summary

Objectives

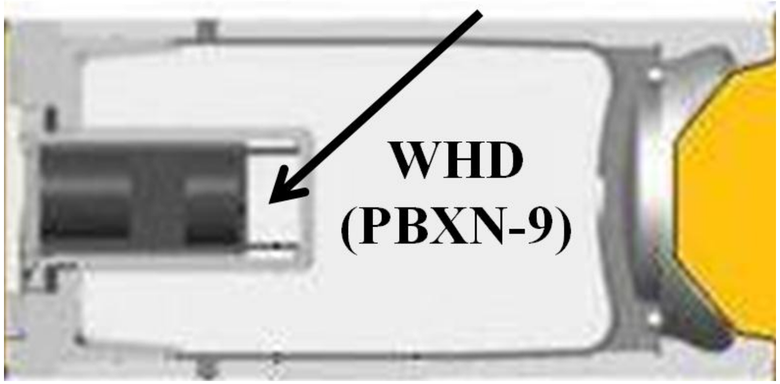
- To develop an explosive replacement for PBXN-9 in the Excalibur M982 155mm Warhead.
  - Utilizing a melt-cast explosive in a pressable form
  - Not intended as a PBXN-9 system-wide replacement
  - Specific to the M982 with transition potential to systems and applications with similar performance requirements.



- Demonstrate explosive replacement in tactical SCO, BI and FI IM Tests.

Program Description

- M982 contains a PBXN-9 HE fill
- Fuze protrudes into HE, with a PBXN-9 booster
  - Current booster must initiate the replacement HE fill
  - No detonation train/booster redesign intended
- Current HE is press-loaded, Beer-can shape at the aft end.
  - Replacement HE can be pressable or castable.



Technology Description

- PBXN-9 is a Sensitive Molding Powder
  - High Nitramines
  - Pressed Explosive

- Strategy is to develop a Melt Cast Alternative that will be flaked/granulated for pressing applications
  - Utilize NTIB ingredients
  - Meltable explosive geared towards improved cook-off reactions
  - Expecting reduction in performance as compared to PBXN-9
  - M982 requirements have trade space to accommodating explosives at Comp B energy levels

Explosive Development

- Thermo-chemical calculations were performed on over 40 formulations
- 9 formulations were selected for characterization
  - 5 focused on higher nitramine content to minimize the performance drop-off from PBXN-9
  - Tri-modal mixtures of HMX → Needed for a pourable cast
  - Other formulations tailored with HMX and DNAN targeting improved cook-off response
  - Several formulations leveraged from explosive replacement programs with a similar technical approach

Explosive Development

Name	Energetics	Non-Energetic Binder	Al	Density (g/cc)	Gurney (cal/g)	% N9	Det Velocity (km/s)	% N9	Pressure (Gpa)	% N9
PBXN-9	**HMX**	**DOA/Hitemp**	**No**		**3.04**		**8.55**		**29.5**	
X1	DNAN/HMX	Wax/DOA	No	1.68	2.84	93%	7.93	93%	26.2	89%
X2	DNAN/HMX	Wax/DOA	Yes	1.72	2.93	96%	7.83	92%	25.5	86%
X3	TNT/HMX	Wax/DOA	No	1.72	2.80	92%	7.90	92%	25.6	87%
X4	TNT/HMX	Wax/DOA	No	1.65	2.94	96%	8.08	94%	25.7	87%
X5	DNAN/HMX	None	No	1.75	2.83	93%	8.04	94%	26.4	89%
X6	DNAN/HMX	None	No	1.71	2.80	92%	7.87	92%	24.9	84%
X7	DNAN/HMX	Wax/DOA	No	1.66	2.80	92%	7.81	91%	25.0	85%
X8	DNAN/RDX	None	No	1.76	2.69	88%	7.80	91%	24.6	83%
X9	TNT/HMX	Wax	Yes	1.83	2.92	96%	7.73	90%	27.5	93%
X10	TNT/RDX	Wax	Yes	1.80	2.93	96%	7.70	90%	26.7	90%

- X2 and X5 were too viscous due to the level of nitramines, even using tri-modal mixtures of HMX
- All candidates with DOA migrated in excess, and as the explosive billet is not 100% confined they were eliminated

Explosive Development

- X6, X8, X9 and X10 were characterized for performance and sensitivity:
  - Detonation Velocity
  - Large Scale Gap Test
  - Cylinder Expansion

Name	Cheetah TMD (%)	Cheetah Density (g/cc)	Cheetah: Gurney Energy Cal/g	Cheetah: Det Velocity (km/s)	Cheetah: Pressure (kbar)	Test Data: LSGT	Test Data: Gurney	Test Data: DV
PBXN-9	98	1.72	3.04	8.55	295	210	2.90	8.37-8.43
X6	98	1.71	2.80	7.87	249	181	2.54	7.54
X8	98	1.74	2.68	7.73	240	154	2.44	7.33
X9	98	1.83	2.92	7.73	275	170	2.59	7.58
X10	98	1.80	2.93	7.70	267	166	2.59	7.47

- X8 was selected for further evaluation
  - X8 is the most mature, does not contain aluminum

Final Testing

- Prior to IM testing, detonation tests were performed to ensure the detonation train initiated X8
  - Simulated bodies
  - Identical booster
  - Simulated booster cup and fuze well

- Provides a large scale comparison to PBXN-9

- Done at hot and cold temperatures to identify potential initiation issues at extreme conditions

Hot Tests

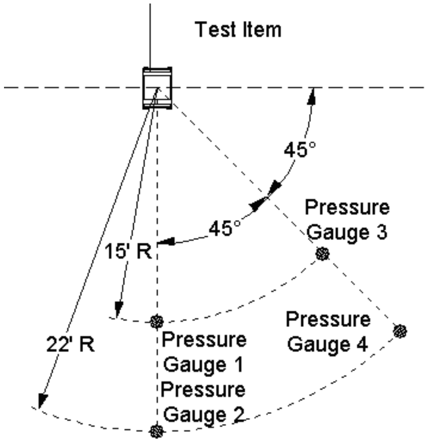

N9
T/S 5


X8
[redacted]
[redacted] HOT
Shot 4
T/S 3
W
[redacted]
HOT
Shot 4
T/S 3
E
[redacted]
HOT

Cold Tests

Cold Tests

- Probes 1 and 3 were located 15' from the test item, at a 45° angle from the test item.
- Probes 2 and 4 were staggered 7' behind probes 1 and 3, 22' from the test item.



Explosive	Condition	Probe 1 (psi - 15ft)	Probe 2 (psi - 22ft)	Probe 3 (psi - 15ft)	Probe 4 (psi - 22ft)
C-4	Ambient	7.8	4.3	7.8	4.4
PBXN-9	Cold	22.5	6.0	21.7	6.9
X8	Cold	12.4	7.2	12.15	8.05
PBXN-9	Hot	17.6	6.6	14.2	9.7
X8	Hot	16.95	6.25	14.15	7.95

Final Testing

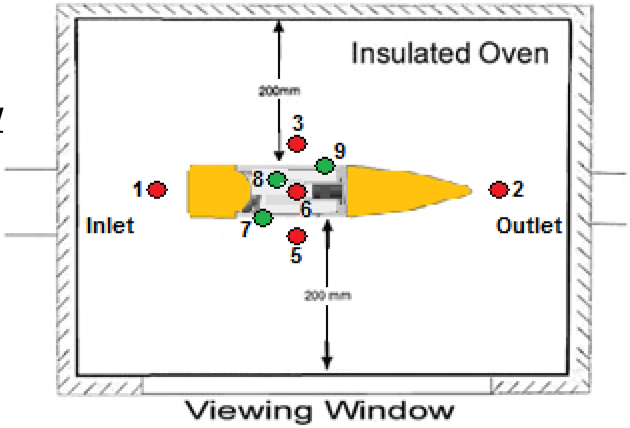
- X8 initiated high order at both Hot and Cold extremes
  - At Hot conditions, it compared favorably to PBXN-9
  - At Cold temperatures, PBXN-9 outperformed
  - Dents and fragment patterns of X8 looked very promising
- X8 was pushed forward for IM Testing
  - SCO at 6F/hr
  - BI with a triple burst
  - FI at 8300 ft/s
- PBXN-9 baseline testing
  - FI a Type (I) → Detonation
  - SCO a Type (II) → Partial Detonation

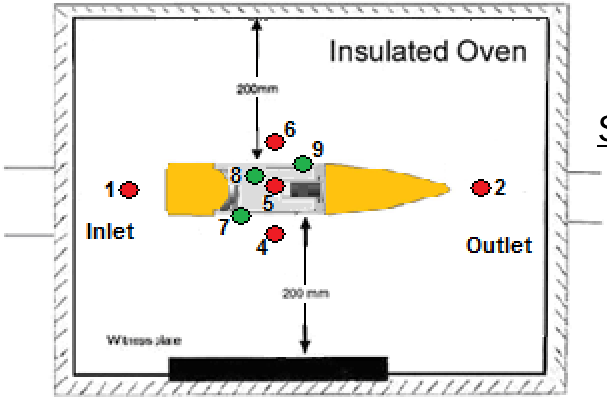
Slow Cook-off Testing Overview

- Test: SCO per STANAG 4382
  - 6F per hour
  - Thermocouples: Three (3) surface, Six (6) air
  - Measurements per 30 seconds

- Configuration: Tactical
  - Horizontal
  - No container was used, previous test results showed same reaction in or out of the container

Top View





Side View

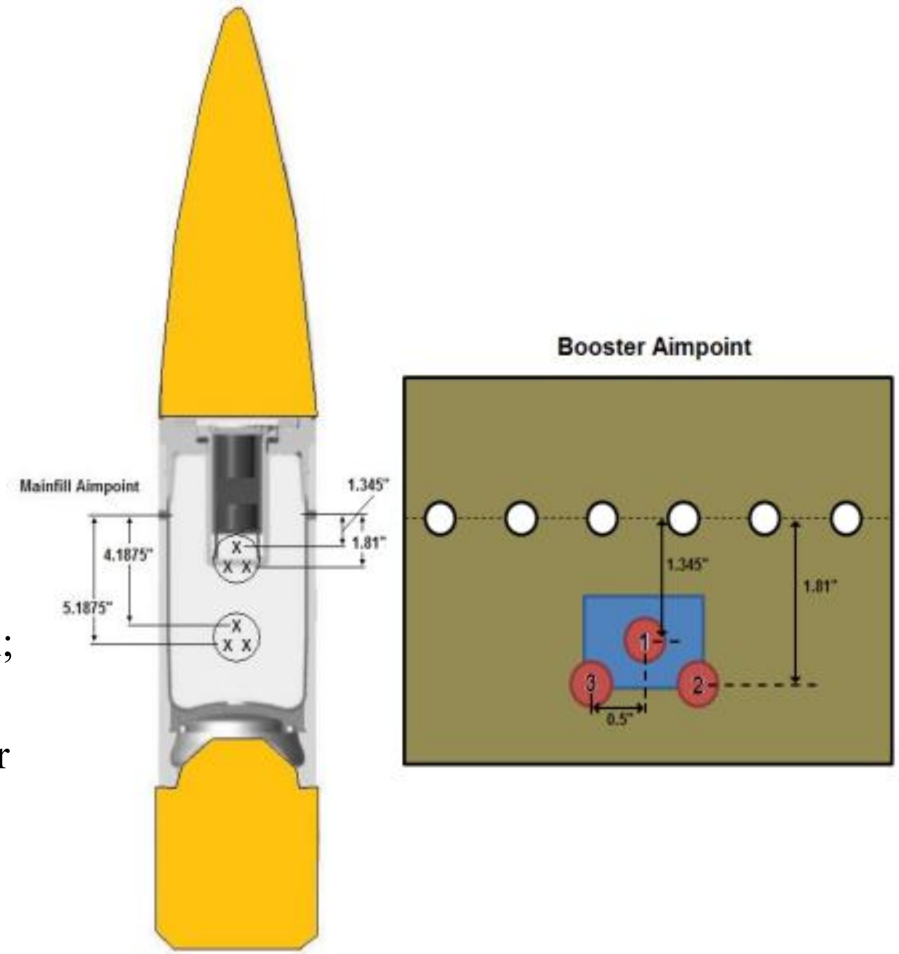
X8 SCO Test

Type II Reaction (Partial Detonation)

Bullet Impact Testing Overview

- <u>Test</u>: Bullet Impact per STANAG 4241
  - ✓ Triple burst 0.50 cal AP bullets
  - ✓ 850 m/s +/- 20 m/s
  - ✓ 600 +/- 50 rounds/min
  - ✓ Aim Points: Aim at main fill & aim at booster

- <u>Configuration</u>: Tactical
  - ✓ No container; not restrained to test stand; vertical; base down
  - ✓ Worst case scenario when round is being set prior to firing



X8: BI Test at Main Fill

Type V Reaction (Burning)

X8 BI Test at Booster

Type IV Reaction (Deflagration)

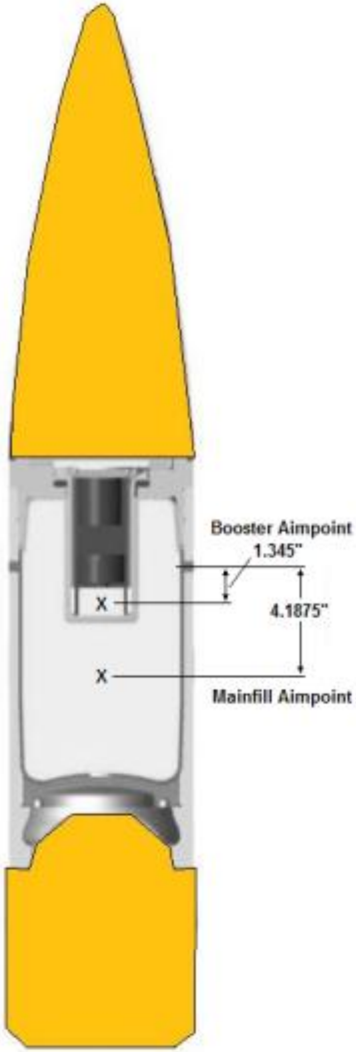
Bullet fired straight through booster

PBXN-9 BI Test at Main Fill

Type IV Reaction (Deflagration)

Fragment Impact Testing Overview

- Test: FI per STANAG 4439
  - Mild-carbon steel conical fragment, 15.556 x 14.3mm at 18.6g
  - 2,530 +/- 90 m/s (8,300 +/- 300 ft/s)
- Configuration: Tactical
  - No container; not restrained; vertical; base down
  - Worst case scenario when round is being set prior to firing



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X8 FI Test at Booster

Type V Reaction (Burning)

Fragment fired straight through booster

X8 FI Test at Main Fill

Type V Reaction (Burning)

IM Testing Overview

- X8 illustrated IM improvements over PBXN-9 in the warhead to penetrating threats.

	SCO	Bullet Impact		Fragment Impact	
		Booster	Main Fill	Booster	Main Fill
PBXN-9	**(II)**	***Not Tested***	**IV**	**(I)**	***Not Tested***
X8	**II**	**IV**	**V**	**V**	**V**

Thermal Testing

- Slow cook-off testing is not indicative of what may happen at the system level with venting solutions.
- Scaled Thermal Explosive Experiments (STEX) were conducted to further examine the cook-off result.
  - Test identifies the vent area required to produce a mild reaction to thermal threats
  - Performed with PBXN-9 and X8
  - Vent area available on M982 is ~2.5 in^2

- Vent area required to produce a mild burning reaction:
  - PBXN-9 = 6.5 in^2
  - X8 = 0.53 in^2

Explosive Development

- To press the melt-cast explosive, explosive flakes are ground to produce granules. The granules are then pressed for billet preparation.
  - There was some concern that the physical grinding was separating ingredients.
  - Batch of the granulated material was sieved to 4 size groups for composition analysis to ensure the integrity of the explosive is maintained.

ID	Size (mm)	Ingredient 1	Ingredient 2	Ingredient 3	Recovery
>6 mesh	> 3.36	+0.6	-0.7	-0.1	99.88
6-10 mesh	2.0 – 3.36	+0.6	-0.7	-0.4	99.67
10-20 mesh	0.84 – 2.0	+0.1	-0.4	-0.4	99.75
20-40 mesh	0.4 – 0.84	-2.4	+0.6	+1.5	99.76

Trends/Conclusions

- As granules are meltable, thermal improvements over traditional pressed explosives can be expected
  - STEX Test Results
- Shock sensitivity increases with granules
  - Increase of ~30cards observed
- Granules have the ability to corner-turn
- Critical diameter decreases
  - Increases applications technology can be associated with: small caliber systems, boosters
- Compositional integrity over majority of the PS distribution

Path Forward

- Looking at alternate methods for producing granules of melt-cast flakes
  - Physical Grinding
  - Slurry Coating
  - Prilling
  - Shock Gel Technology
  - Rotoformer Pastillation

Questions