Presented to:

NDIA IM/EM Symposium

RDECOM

Investigation of Aging Effects on Material Properties, Subscale Hazards and Impact Tests for PBXN-109 and PAX-3

AMRDEC
STRENGTH THROUGH TECHNOLOGY

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Introduction

This task is being done in support of Key Technical Area (KTA) 4-37-08 for the Weapons Technical Panel (WTP) 4 of the Technical Cooperation Program (TTCP).

The objective of this KTA is to investigate the influence of aging on the Insensitive Munitions (IM) response of explosives. This will provide greater confidence in the results from material studies, small-scale testing, and modelling & simulation.

This particular effort will explore the effects of thermally induced aging on two explosives, PBXN-109 and PAX-3. The explosive materials will be aged as bare billets and also in generic titanium warhead cases.

The bare material will be subjected to material characterizations for comparison to baseline values.

The surrogate warheads will be subject to Fragment Impact testing also for comparison to results from, unaged, baseline assets.

Background

In order to address the critical void of information on potential changes to IM behavior as warheads age, the following tasks will be undertaken:

- **Perform literature review of historical IM reports for the surrogate warhead configuration, and material characterization data for two PBXN-109 and PAX-3 explosive.**

- **Remove PBXN-109 billets from existing surrogate warheads. Machine PAX-3 billets and bond into the warhead cases. 4 PBXN-109 billets will be used to conduct baseline material characterization. 4 more will be subjected to accelerated aging. Similarly, 2 PAX-3 billets will provide material for baseline testing and 4 will be aged. 3 warheads of each fill will be used for baseline FI testing. 12 surrogate warheads of each fill will be subjected to aging and pulled at specified intervals for FI testing.**

- **The material characterization testing will include mechanical and chemical properties as well as subscale hazards.**

- **Data from aged material will be compared to the baseline values in an effort to identify aging trends which could in turn be used as models for predicting IM response in aged assets.**

Test Plan

Chemical Tests:
- **Vacuum Stability using Procedure 2 of STANAG 4556**
- **Differential Scanning Calorimeter using STANAG 4515, Method 202.01.020 of AOP-7**
- **Composition Analysis using High Performance Liquid Chromatography (HPLC) or Gas Chromatography/Mass Spectroscopy (GC?MS)**
- **Bulk Density**
- **Total Volatiles using method 101.6 of MIL-STD-650**

Mechanical Tests:
- **Compression using STANAG 4443 (for PAX-3 only)**
- **Uniaxial Tensile Testing using STANAG 4581 and 4506 (for PBXN-109 only)**
- **Dynamic Mechanical Analysis (DMA) using STANAG 4581 and 4506**
- **Shore A Hardness using ASTM D2240-00 and MIL-E-82886**

Subscale Hazards Tests:
- **Drop Weight Impact (Bureau of Mines) using Method 201.01.001 of AOP-7**
- **Sliding Friction using Method 201.02.005 of AOP-7**

Fragment Impact:
- **STANAG 4496 specified projectile, 6,000 ft/sec alternative impact velocity**

Accelerated Aging Plan

- An Accelerated Aging Program was initiated in which bare explosive billets as well as surrogate warheads will be subjected to intervals of storage at an elevated temperature (60°C) to achieve a certain equivalent age (5, 10, 15, 20 years equivalent).

- Aging intervals were based on standard protocols in AOP-48, AOP-7 and previous aging data where available

		Time at 60°C			
	Baseline	4 months	9 months	13 months	17 months
Material Testing	X	X	X	X	X
FI Testing	X	X	X	X	X
Equivalent Age	0	5 yrs	10 yrs	15 yrs	20 yrs

•For each aging interval, chemical, mechanical and subscale hazard testing will be repeated on both PBXN-109 and PAX-3 billets.

•For the baseline Fragment Impact (FI) Testing, and for each aging interval, three surrogate warheads of each explosive will be tested with the NATO standard fragment. Impact velocity will be selected to be the highest velocity which can be reliably achieved with the AMRDEC 20mm gun .

PBXN-109 Billet and Warhead

PBXN-109 Billet
-Cast Configuration
-Removed from case
-Approx. 7 lbs N.E.W.

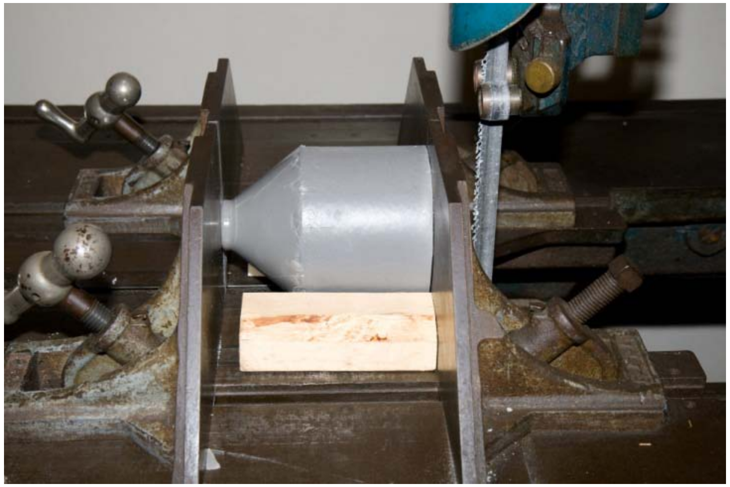
PBXN-109 Surrogate Warhead
- **With and without explosive billet**
- **Removed using thermal cooling to fracture wax bondline**

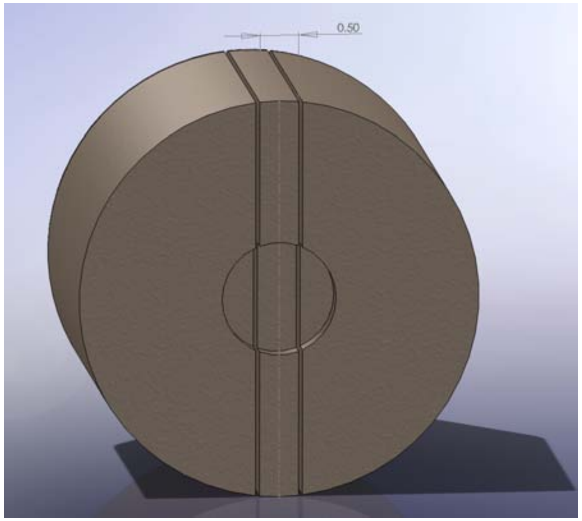
PAX-3 Billet and Machined Configuration

As Received　　　　Machined for Bonding into Cases

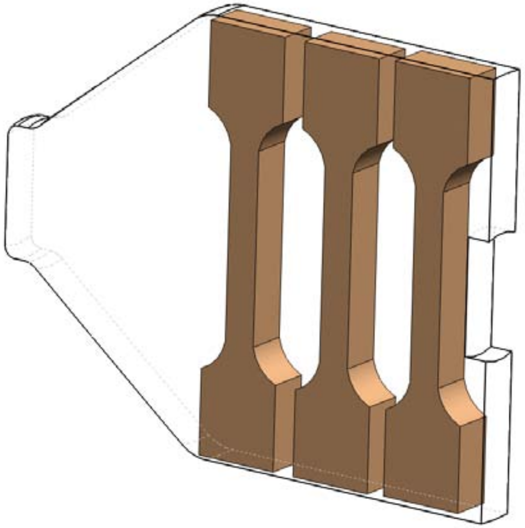
Compatibility and Cure Studies identified HTPB as the best candidate to bond the machined PAX-3 billets into the titanium warhead cases.

Production of PBXN-109 Uniaxial Test Samples





PBXN-109 Warhead Billet Configuration & Dissection for Tensile Samples



Results to Date

PBXN-109 Mechanical Property Results:

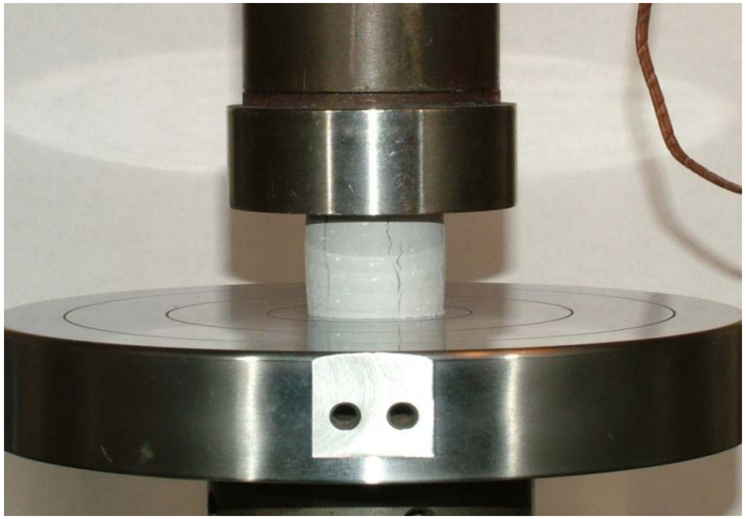
PBXN-109 Billet	Sample	Max Stress (psi)	Minimum Required Max Stress (psi)	Strain @ Max Stress (%)	Minimum Required Strain @ Max Stress (%)
1	1	93.0	60C	19.1	12
	2	89.4		19.2	
	3	89.8		18.8	
2	1	106.5		17.6	
	2	107.9		16.1	
	3	110.0		15.7	
3	1	90.2		18.9	
	2	92.6		20.4	
	3	95.7		18.0	
4	1	98.0		17.9	
	2	97.0		19.0	
	3	93.2		20.0	

- Tests conducted at ambient temperature (+25^{o} C) and 1.35mm/mm/min strain rate
- Results meet required values from MIL-E-82886, PBXN-109 production specification

Results to Date

PAX-3 Compression Test Results:

Test Temperature (°C)	Max Load (lb)	Max Strength (psi)	Strain at Max Strength (%)	Tangent Modulus (psi)
+60	533	677	10.9	12168
+25	2484	3163	9.51	40228
-31	6924	8801	8.20	226502



Compression Test Set Up
PAX-3 Sample Under Compression

- Compression testing per STANAG 4443
- Very high material stiffness, due to density, and press forming of billets at high pressure
- Moderate nonlinear elasticity exhibited at ambient temperature (not brittle).

Results to Date

Shore A Hardness Measurements:

PBXN109 Billet	Hardness Value	PBXN-109 Specified Minimum Value	PAX-3 Billet	Hardness Value
1	54.0	30	279	89.5
2	60.1		280	89.8
3	52.8			
4	53.1			

- Measured hardness values for PBXN-109 met specification requirements.
- No specification requirement found for PAX-3

Results to Date

Drop Weight Impact Results: (Bureau of Mines)

Test sample	50% drop height (cm)
RDX (Type II, Class 5)	27.0
PBXN-109 Billet 1	20.9
PBXN-109 Billet 2	20.0
PAX-3 Billet 279	25.1
PAX-2 Billet 280	27.8

- Tested in accordance with modified Bruceton Method

Examples of negative and positive impact test results

Results to Date

Sliding Friction Test Results:

Billet	Bruceton value
PBXN-109 1	1957.34
PBXN-109 2	2187.76
PAX-3 279	1318.26
PAX-3 280	1318.26

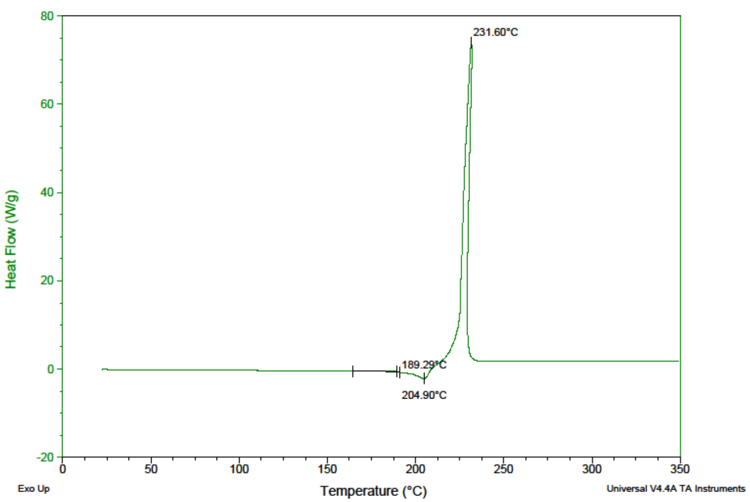
- For each explosive, 20 samples tested in accordance with modified Bruceton Method
- Linear velocity = 2.44 m/sec
- MIL-E-82886 does not have a specified requirements for PBXN-109. No specified value at the same test parameters was found for PAX-3

ABL Sliding Friction Test Apparatus

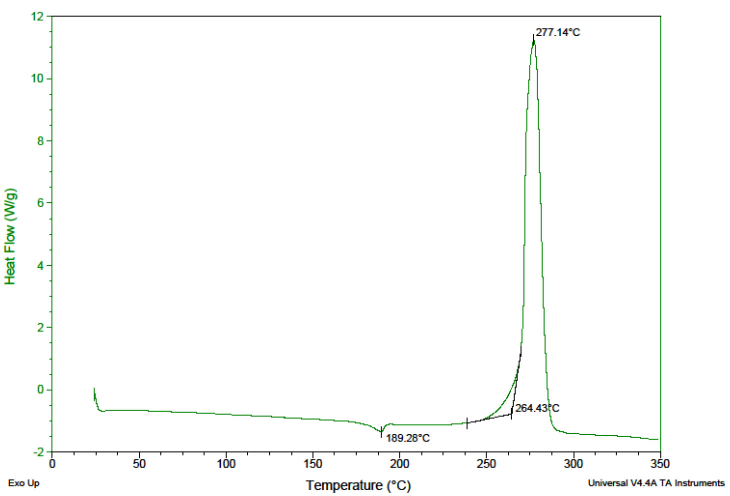
Results to Date

Differential Scanning Calorimeter Results:

Billet	Onset Temp (°C)	Endotherm (°C)	Exotherm Max (°C)
PBXN-109 1	189.6	205.7	234.1
PBXN-109 2	189.5	205.7	232.6
PBXN-109 3	189.4	206.6	231.2
PBXN-109 4	189.7	205.8	236.2
PAX-3 279	261.5	187.5	276.4
PAX-3 280	264.6	190.1	277.3



Example PBXN-109 DSC Plot



Example PAX-3 DSC Plot

Results to Date

Vacuum Stability Test Results:

Billet	Gas Generated (cc/g)
PBXN-109 1	0.216
PBXN-109 2	0.233
PBXN-109 3	0.194
PBXN-109 4	0.193
PAX-3 279	0.098
PAX-3 280	0.143

- **Test conducted according to STANAG 4556, Procedure 2**
- **Samples held at 100°C for 48 hours**
- **Results for PBXN-109 were below the maximum allowed value in MIL-E-82886**

Results to Date

Bulk Density Measurement Results:

Number of billets tested	Avg Density (g/cc)	Minimum specified density (g/cc)	Maximum specified density (g/cc)
4 PBXN-109	1.67	1.6	1.7
2 PAX-3	1.87	unknown	unknown

- **Measurements made with stereopyncnometer**
- **Measured density for PBXN-109 is within the specified range in MIL-E-82886**

Results to Date

Chemical Composition Analysis Results: PBXN-109 Plasticizer and Antioxidant

Constituent	PBXN-109 Billet	Measured Level (%)	Min/Max Specified Value (%)
Plasticizer, DOA	1	7.57	7.0/7.5
	2	7.41	
	3	7.81	
	4	7.49	
Antioxidant	1	0.002	0.09/0.11
	2	0.002	
	3	0.003	
	4	0.003	

- **Measured DOA level is at the high end of maximum value specified in MIL-E-82886**
- **Measured level of 2,2'-methylenebis, antioxidant, is well below minimum required value in MIL-E-82866**
- **These test results are being reviewed for accuracy. Tests will be repeated if necessary to validate the baseline values.**

Results to Date

Chemical Composition Analysis Results: PAX-3

- **High Performance Liquid Chromatography (HPLC) and Gas Chromatography/Mass Spectroscopy (GC/MS) analysis of PAX-3 found primary known constituents, HMX, aluminum and BDNPF/A**

- **No contaminants were found**

Conclusions

- **Most of the baseline material characterization has been completed for both PBXN-109 and PAX-3.**

- **The accelerated aging program has been initiated. Samples aged for four months have been pulled and material characterization testing is underway.**

- **Fragment Impact testing on baseline and 4 month aged surrogate warheads with PBXN-109 and PAX-3 will be conducted shortly**

- **As data on aged samples becomes available, it will be compared to baseline values to identify any aging trend**

- **Results will continue to be documented and presented to the IM Technical community**