ACCELERATED AGING STUDY OF PBXN-109 FORMULATED WITH RDX FROM SEVERAL SOURCES

K. A. Clark and B. P. Thomas
Naval Surface Warfare Center, Indian Head Division
Indian Head, Maryland 20640

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Agenda

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- RDX source selection
- Preparation of PBXN-109 samples
- Aging Protocol
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Program Objective

The objective of this accelerated aging study was to begin addressing the concept of IM persistence through aging.

- Does the RDX formulation remain insensitive through the duration of an aging cycle?
- Can IM-ness be successfully assessed at the laboratory scale?

RDX Source Variants

- **RDX and PBXN-109 provided in collaboration with the Reduced Sensitivity RDX Round Robin (R4) Program**
- Australian Defence Industries (ADI)
- BAE SYSTEMS Ordnance Systems Inc. (OSI). OSI is the operating contractor of the US Holston Army Ammunition Plant.
- BAE SYSTEMS Royal Ordnance Defence (RO)
- DYNO Nobel ASA, Defence Products (DN). (Two RDX variants)
- European Energetics Cooperation (EURENCO). EURENCO is jointly owned by SME (SNPE Matériaux Energétiques), Saab, and Patria. (Two RDX variants)

Preparation of PBXN-109 Samples with RDX Source Variants

PBXN-109 Formulation	
	Weight Percent
R45HT NCO/OH: 1.00	7.3460%
DOA	7.3460%
AO 2246	0.1000%
TPB	0.0050%
DHE	0.2600%
Al MDX-81	20.000%
RDX Class 1	64.00%
IPDI	0.9308%

RDX Class 1		
Sample		Manufacturing Process
IH21005GXN109-0300	Royal Ordnance Type 1 Class 1	Woolwich
IH21005GXN109-0301	MI-RDX Conventional Class 1	Woolwich
IH21005GXN109-0302	I-RDX Eurenco Class 1	Woolwich
IH21005GXN109-0303	ADI Class 1 Grade A	Woolwich
IH21005GXN109-0306	OSI Holston Type II Class 1	Bachman
IH21005GXN109-0307	Dyno RS-RDX Class 1	Bachman
IH21005GXN109-0308	Dyno Type II Class 1	Bachman

Preparation of PBXN-109 Samples with RDX Source Variants

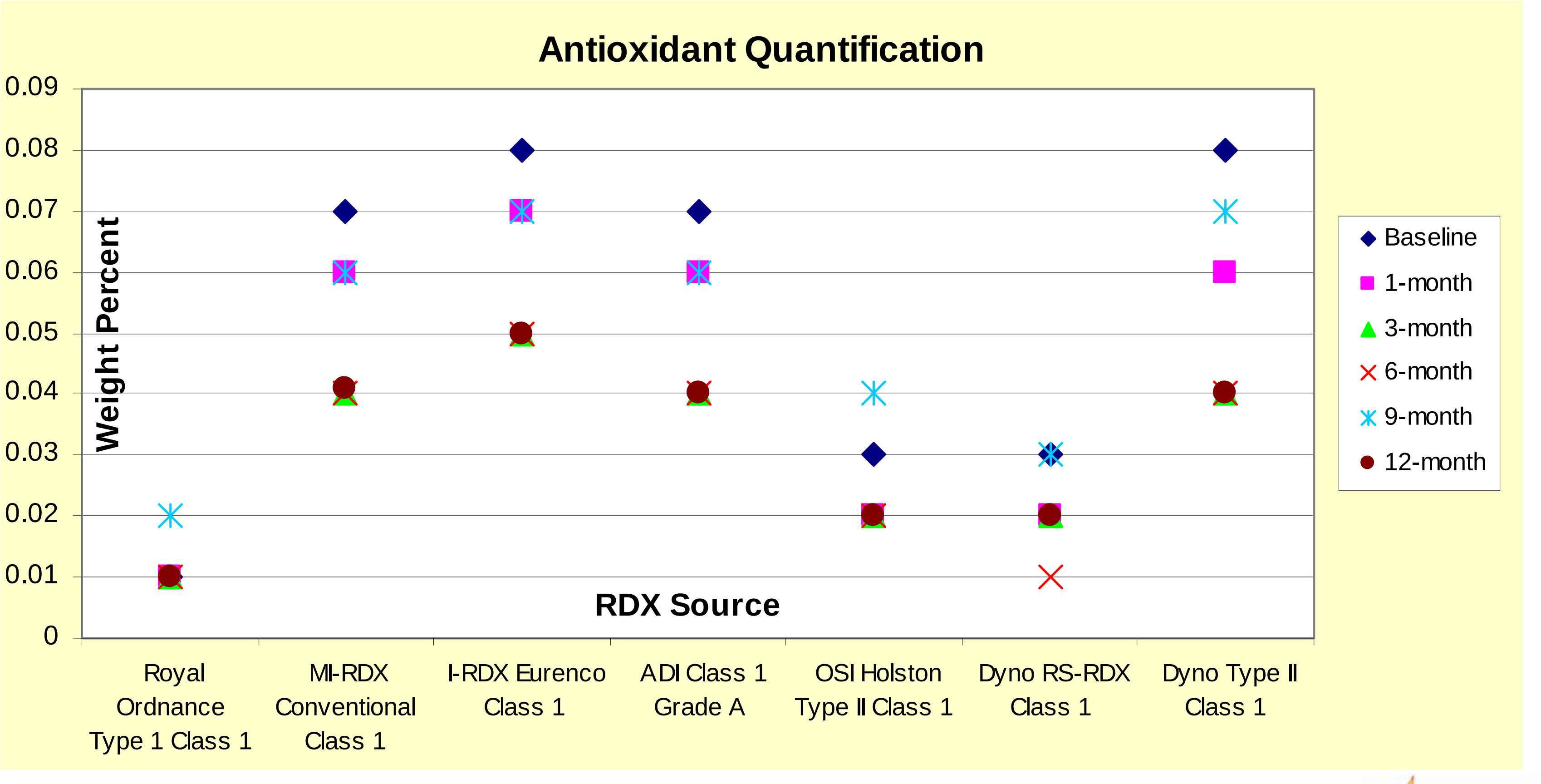
During the loading of the baseline IMAD Gap Test hardware, an additional set of gap test hardware was loaded from each mix, along with pan samples which were stored under controlled conditions at 25ºC in desiccators under a nitrogen purge to maintain their original integrity.

Aging Protocol

- Two PBXN-109 pan samples were aged for 12 months at 70°C with withdrawals at 3-month time intervals (t-0, t-3, t-6, t-9 and t-12).
  - Hazards Analysis (ESD, Impact, Friction)
  - DMA
  - Plasticizer
  - Mechanical Properties
  - HFC
  - Antioxidant
  - Rapid Screening Device (RSD)
- Material quantity restraints prevented a diurnal type aging profile.
- Material quantity restraints prevented the introduction of controlled variations in the oxygen and/or humidity conditions of munition storage.

Antioxidant Analysis

Antioxidant Quantification (Weight Percent)



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Plasticizer Analysis

Plasticizer Quantification

- The analysis of the plasticizer content within the aged samples was terminated for the duration of the aging program after the 3-month aging withdrawal.

- The measured plasticizer data may be skewed by the possibility of AO dissolving and migrating within the PBXN-109 binder system during the accelerated aging process.

RSD Analysis

Sample	RDX
Lot 300	Royal Ordnance Type 1 Class 1
Lot 301	MI-RDX Conventional Class 1
Lot 302	I-RDX Eurenco Class 1
Lot 303	ADI Class 1 Grade A
Lot 306	OSI Holston Type II Class 1
Lot 307	Dyno RS-RDX Class 1
Lot 308	Dyno Type II Class 1

Maximum Pressure (bar) Zero-time							
LOT #	300	301	302	303	306	307	308
Sample 1	15.6	13.7	19.8	16.1	14.5	14.9	5.9
Sample 2	12.5	13.8	15.4	9.2	4.2	13.9	5.8
Avg.	14	14	18	13	9	14	6
Std. Dev.	2	0.1	3	5	7	0.7	0.1

6 Months Aged							
LOT #	300	301	302	303	306	307	308
Sample 1	6.7	5.4	5.9	6.3	6.8	6.3	15.5
Sample 2	6.0	6.1	6.7	6.0	6.3	6.6	14.6
Avg.	6.4	5.8	6.3	6.2	6.6	6.5	15.1
Std. Dev.	0.5	0.5	0.6	0.2	0.4	0.2	0.6

12 Months Aged							
LOT #	300	301	302	303	306	307	308
Sample 1	11.5	13.7	16.1	11.2	13.9	15.1	15.1
Sample 2	14.4	15.3	Leak	16.5	15.6	16.1	12.2
Avg.	13.0	14.5	16.1	13.9	14.8	15.6	13.7
Std. Dev.	2.1	1.1	#DIV/0!	3.7	1.2	0.7	2.1

RSD Analysis

Sample	RDX
Lot 300	Royal Ordnance Type 1 Class 1
Lot 301	MI-RDX Conventional Class 1
Lot 302	I-RDX Eurenco Class 1
Lot 303	ADI Class 1 Grade A
Lot 306	OSI Holston Type II Class 1
Lot 307	Dyno RS-RDX Class 1
Lot 308	Dyno Type II Class 1

IGNITION TEMPERATURE (DEG C) Zero-Time							
LOT #	300	301	302	303	306	307	308
Sample 1	216	225	225	222	221	215	210
Sample 2	226	218	215	220	221	218	223
Avg.	221	222	220	221	221	217	217
Std. Dev.	7	5	7	1	0	2	9

6 Months Age							
LOT #	300	301	302	303	306	307	308
Sample 1	218	216	222	218	220	220	220
Sample 2	216	215	223	216	220	213	220
Avg.	217	216	223	217	220	217	220
Std. Dev.	1	1	1	1	0	5	0

12 Months Age							
LOT #	300	301	302	303	306	307	308
Sample 1	211	226	217	216	229	211	217
Sample 2	225	220	210	222	219	215	221
Avg.	218	223	214	219	224	213	219
Std. Dev.	10	4	5	4	7	3	3

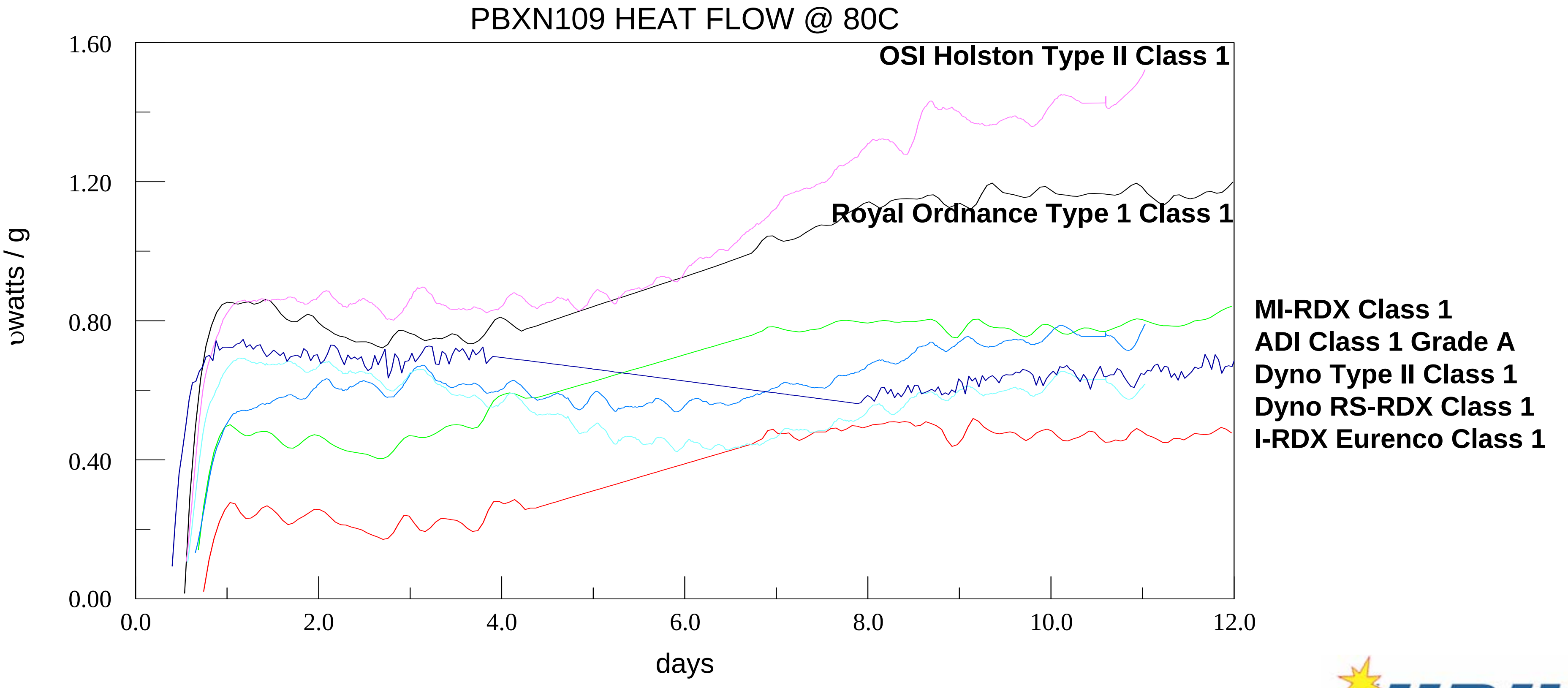
DMA Analysis

DMA Analysis

All PBXN-109 samples yielded the same glass temperatures (-90°C) within the precision of the instrument over the twelve-month aging period. DMA testing was performed on the TA Instruments Model Q800.

Heat Flow Calorimetry

Baseline, (t-0) HFC Data



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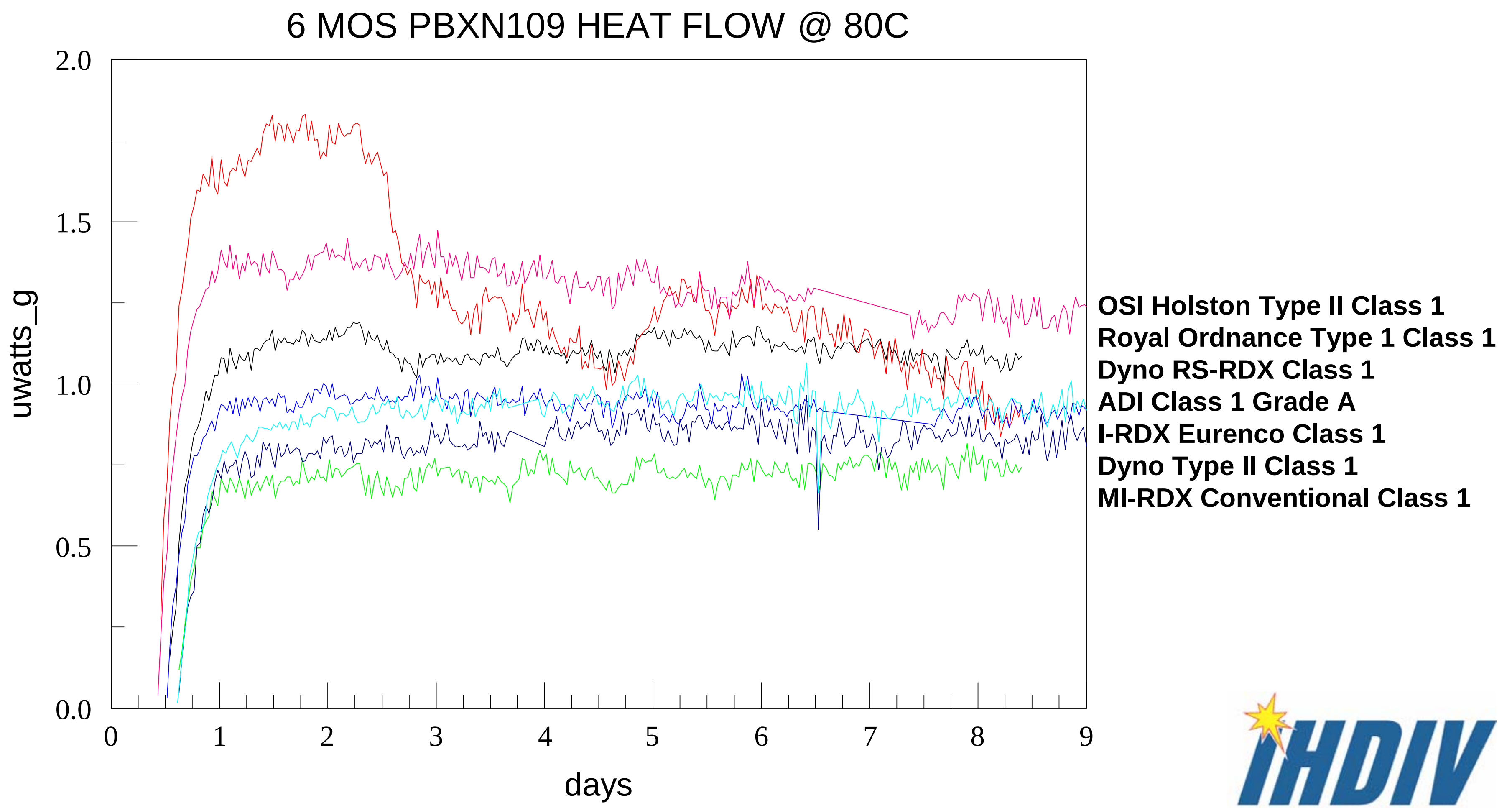
Heat Flow Calorimetry

6-Month, (t-6) HFC Data



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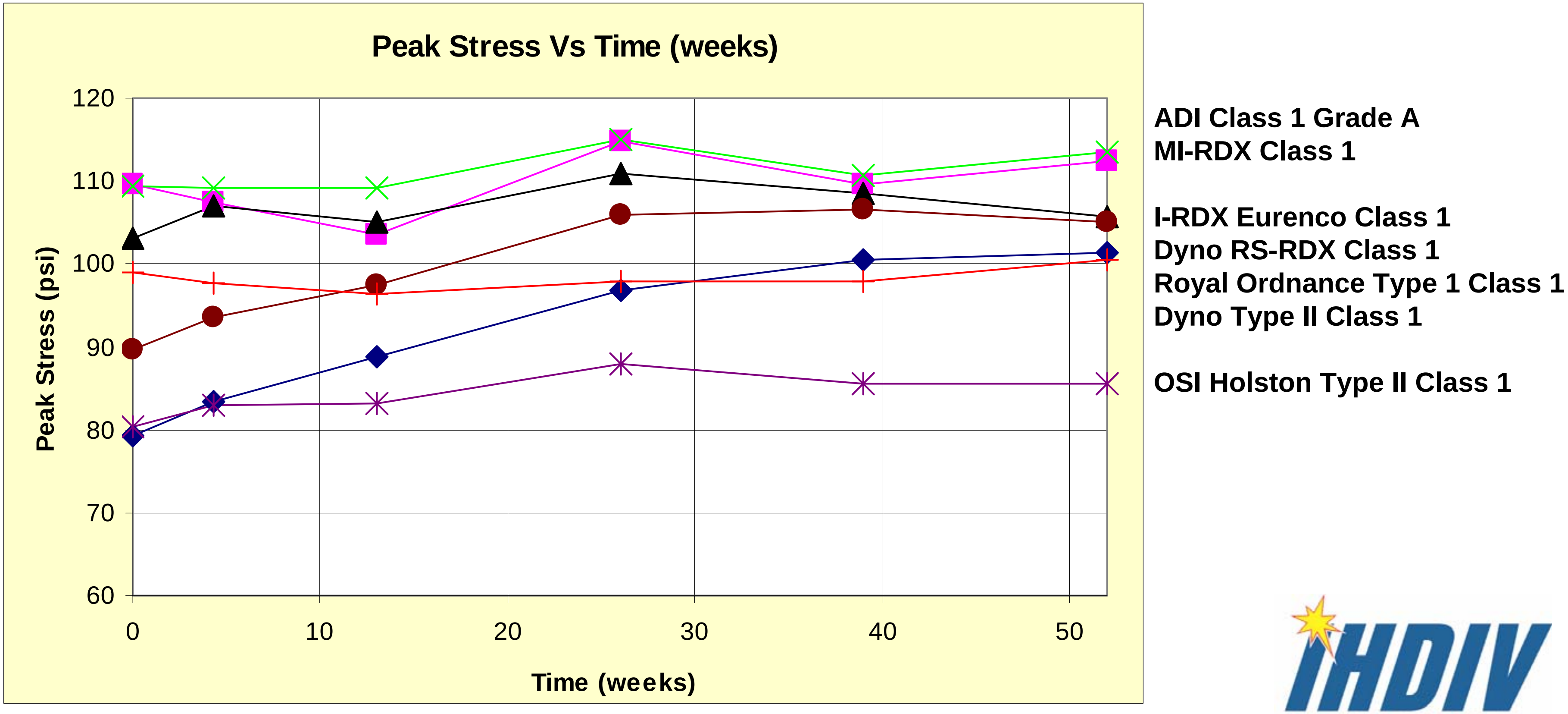
Mechanical Properties

Max Stress

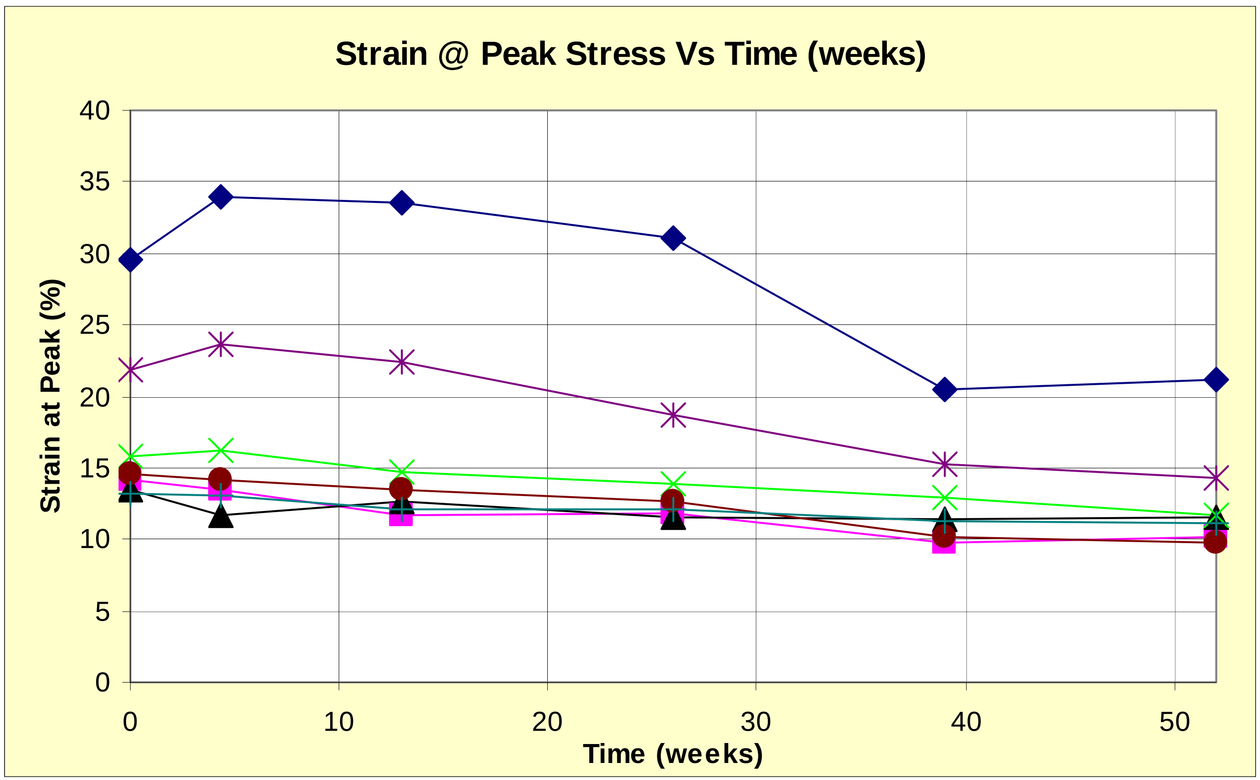
- Baseline max stress values varied across the seven lots from 80psi to 110psi.
- All lots showed an expected increase of 15-20% over the elapsed twelve months of aging.



Mechanical Properties

Strain at Max Stress

- All lots demonstrated a slight downward trend in the observed strain at max stress.
- Royal Ordnance and OSI Holston exhibited an extended (mesa type) plastic strain region.
- Ensured an increase in the max stress with an increase in max strain over time.
- Result is a strengthening within elongation during aging.

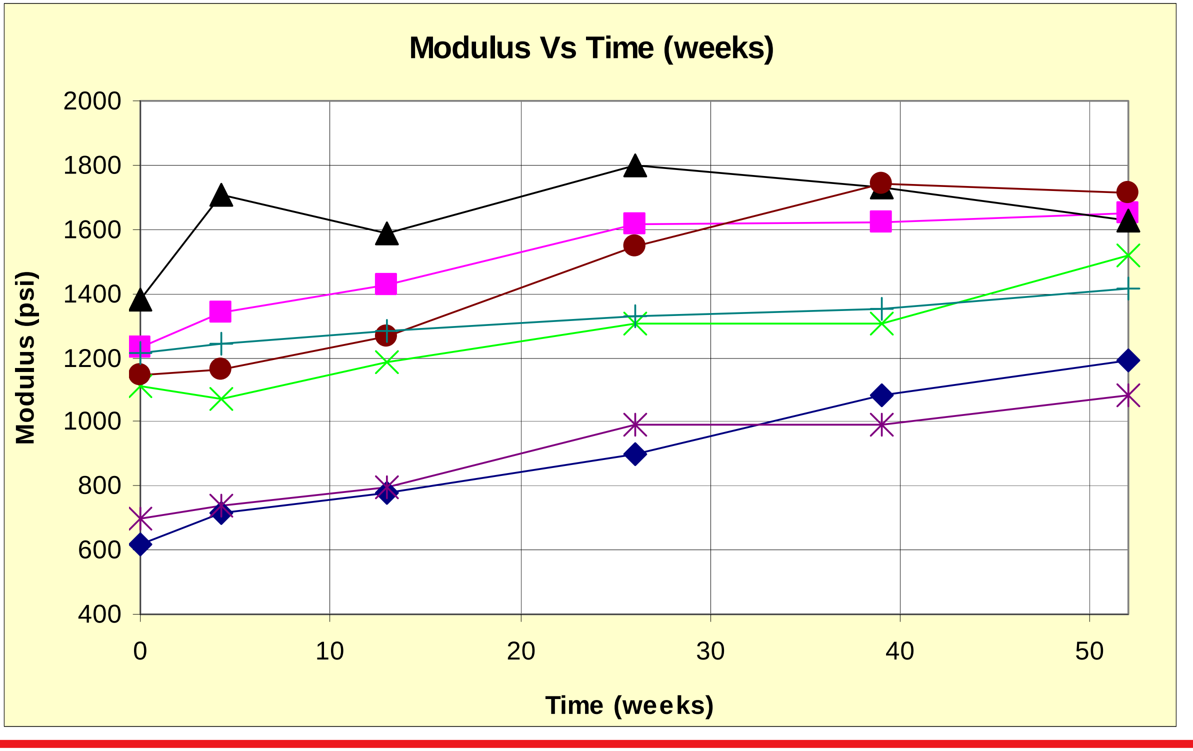


Royal Ordnance Type 1 Class 1
OSI Holston Type II Class 1
ADI Class 1 Grade A
Dyno Type II Class 1
I-RDX Eurenco Class 1
MI-RDX Class 1
Dyno RS-RDX Class 1

Mechanical Properties

Modulus

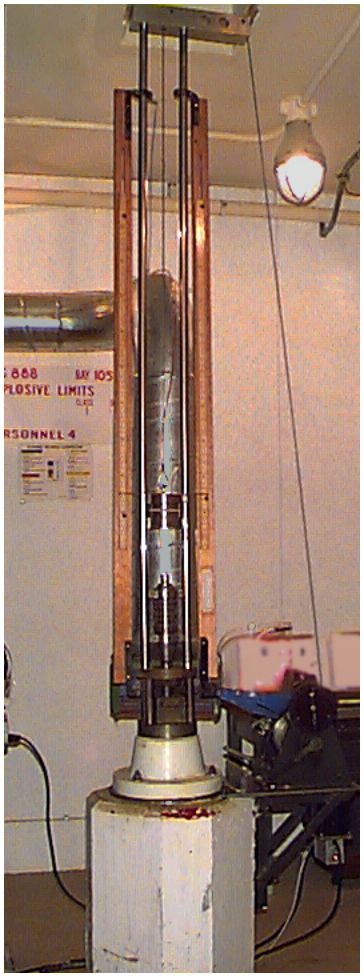
- The baseline modulus varied from 600psi to 1400psi.
- Most lots are showing an as expected increase in modulus with time.
- All lots except Dyno Type II Class 1 are increasing at a rate of 20-30% in the elapsed twelve months.
- Royal Ordnance and OSI Holston have a significantly smaller modulus. This modulus is very characteristic of classic PBX's.



Dyno RS-RDX Class 1
MI-RDX Class 1
I-RDX Eurenco Class 1
ADI Class 1 Grade A

Royal Ordnance Type 1 Class 1
OSI Holston Type II Class 1

Hazards Characterization



	Baseline NOS Impact (mm)	6-month NOS Impact (mm)	12-month NOS Impact (mm)
Royal Ordnance Type 1 Class 1	447 Low	378 Med	322 Med
MI-RDX Class 1	391 Med	376 Med	287 Med
I-RDX Eurenco Class 1	322 Med	316 Med	391 Med
ADI Class 1 Grade A	333 Med	348 Med	391 Med
OSI Holston Type II Class 1	511 Low	851 Low	492 Low
Dyno RS-RDX Class 1	391 Med	383 Med	299 Med
Dyno Type II Class 1	355 Med	383 Med	293 Med
RDX Standard	261 Med	293 Med	293 Med

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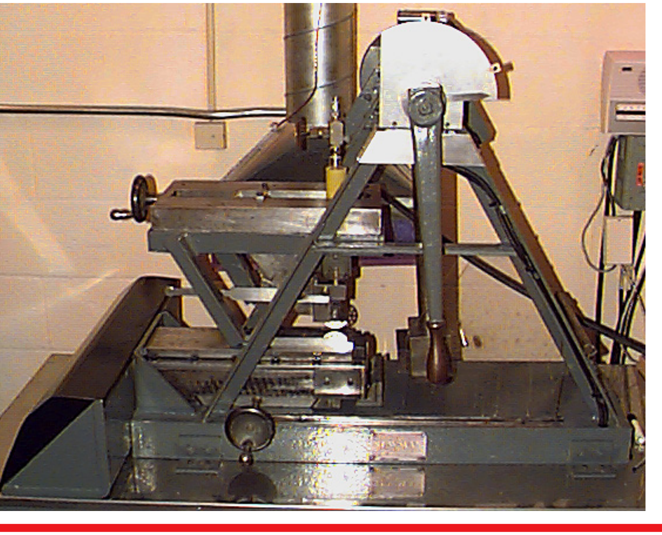
Hazards Characterization

	Baseline ABL Friction (psig)	6-month ABL Friction (psig)	12-month ABL Friction (psig)
Royal Ordnance Type 1 Class 1	560 Low	235 Med	750 Low
MI-RDX Class 1	750 Low	560 Low	420 Med
I-RDX Eurenco Class 1	560 Low	560 Low	235 Med
ADI Class 1 Grade A	235 Med	560 Low	235 Med
OSI Holston Type II Class 1	420 Med	750 Low	560 Low
Dyno RS-RDX Class 1	420 Med	560 Low	560 Low
Dyno Type II Class 1	560 Low	235 Med	5605 Low
RDX Standard	100 Med	180 Med	135 Med



Hazards Characterization

	Baseline ESD (joules)	6-month ESD (joules)	12-month ESD (joules)
Royal Ordnance Type 1 Class 1	0.037 Med	0.015 High	0.010 High
MI-RDX Class 1	0.037 Med	0.015 High	0.010 High
I-RDX Eurenco Class 1	0.037 Med	0.015 High	0.015 High
ADI Class 1 Grade A	0.023 High	0.015 High	0.010 High
OSI Holston Type II Class 1	0.023 High	0.023 High	0.015 High
Dyno RS-RDX Class 1	0.023 High	0.037 Med	0.015 High
Dyno Type II Class 1	0.023 High	0.023 High	0.010 High
RDX Standard	0.095 Med	0.165 Med	0.165 Med

Summary

- Royal Ordnance Type 1 Class 1 RDX and OSI Holsten Type II Class 1 RDX demonstrated better mechanical aging characteristics than the rest of the studied population.
- The following material characteristics varied little over the aging cycle for all samples:
  - Plasticizer amount
  - Antioxidant depletion
  - Glass transition temperatures
  - Ignition temperature
  - Off-gassing pressure
- Royal Ordnance Type 1 Class 1 RDX and OSI Holsten Type II Class 1 RDX maintained a level of lower hazard sensitivity characteristics throughout the aging study; OSI Holsten Type II Class 1 RDX demonstrated no increase in impact sensitivity and a decrease in friction sensitivity.

Planned Future Efforts

Further progression of this study will include the aging of PBXN-109 formulated with insensitive RDX that has been loaded into a relevant warhead and aged. The PBXN-109 propellant would be extracted and analyzed with an emphasis on the chemical, physical, mechanical properties and performance changes of PBXN-109 from the aging of the warhead.

The additional phase of this study will focus on the aging of PBXN-109 formulated with insensitive RDX aged at three different temperatures. This endeavor will provide kinetic data for the aging of the propellant. The attained information will enable a series of calculations to analyze the particle binder interface and the effect that aging has upon this interaction.

Acknowledgments

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Points of Contact

Dr. Kerry A. Clark, Code E131C
kerry.a.clark@navy.mil
301-744-4102
NSWC-IHDIV
4103 Fowler Road Suite 107
Indian Head, MD 20640-5106

Mr. Bruce P. Thomas, Code E13E
bruce.p.thomas@navy.mil
301-744-6521
NSWC-IHDIV
4103 Fowler Road Suite 107
Indian Head, MD 20640-5106

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Questions