



# 49TH ANNUAL FUZE CONFERENCE

**R. Hutcheson**  
Indian Head Division  
NAVSEA Surface Warfare Center

## **MK 80 MOD 0 FUZE BOOSTER: AN INSENSITIVE MUNITIONS (IM) REPLACEMENT FOR THE MK 44 MOD 1 FUZE BOOSTER**

**Craig Cornish**  
Technology Division  
Weapons Department  
Indian Head Division  
NAVSEA Surface Warfare Center

**Harold McMillan**  
Code G22  
Dahlgren Division,  
NAVSEA Surface Warfare Center



Distribution statement A: Unlimited - Approved for Public Release



*Making Sea Power 21 a Reality*

# ACKNOWLEDGEMENTS



- **Wish To Thank The Following Groups For Their Support:**
  - IHD/NSWC For Their Support In Environmental And Performance Testing During The Development Of The Mk 80 Fuze Booster
  - NSWCDD For Their Support In Environmental And IM Testing During The Development Of The Mk 80 Fuze Booster
  - Raytheon For Their Support Throughout This Program
  - Reynolds System Inc. For Their Support In Manufacturing And Follow-on Work In Aging Testing To Support The Integration Of The Mk 80 Fuze Booster Into The AMRAAM System.

# BACKGROUND



- The AMRAAM WDU-41/B Warhead Failed Fast Cook-off (FCO), Slow Cook-off (SCO) and Fragment Impact (FI) Insensitive Munitions (IM) Tests



	FCO	SCO	BI	FI	SD
WDU-41/B WHD (PBXN-110:~15 lbs.)	Defl	Defl	Burn	Expl Det*	Pass

\*Impact to CH-6 Booster

## – AMRAAM Warhead IM Mitigation Concepts:

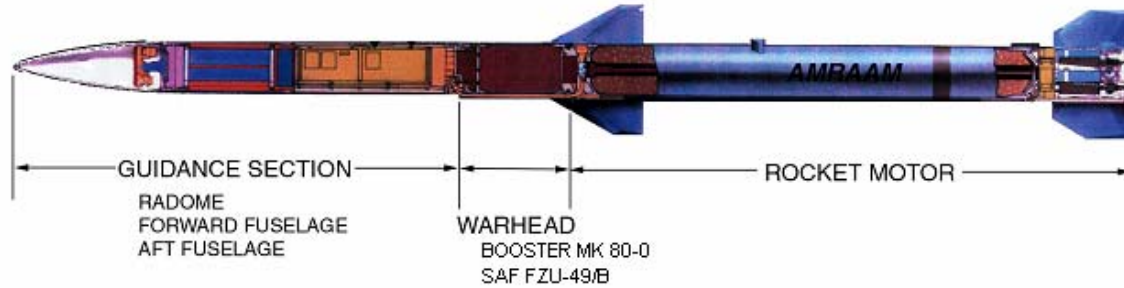
- **Composite Closure Plate – Unsuccessful, concept discontinued**
  - No significant FCO or SCO mitigation observed at the system level
- **Alternate Booster Explosive – Successful, concept continued**
  - Significant FI mitigation at the system level



# OBJECTIVE

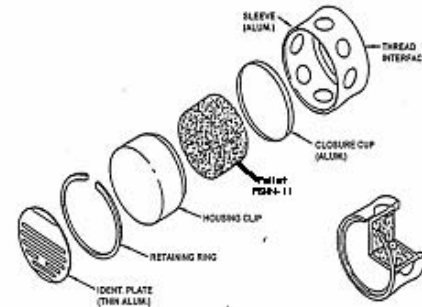
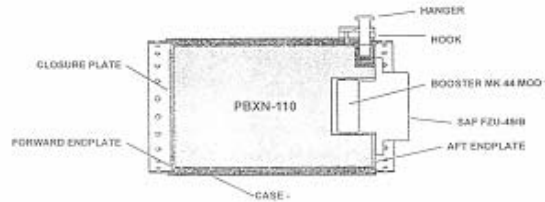
- **To Identify A Safe And Suitable Replacement For The AMRAAM Booster Explosive, CH-6, To Address FI Test Requirements**
- **Alternate Booster Explosive program sponsored by the AMRAAM Program Office, Navy Insensitive Munitions Advanced Development (IMAD) program and Insensitive Munitions Technology Transition Program (IMTTP)**

# AMRAAM AIM-120 MISSILE CONFIGURATION



AMRAAM AIM-120  
WARHEAD WDU-41/B

MK 80 MOD 0 Booster  
- PBXN-11 Pellet



# APPROACH



## Phase I: Preliminary Testing and Explosive Down Selection

- Identify field of candidate explosives for evaluation
- Conduct preliminary evaluation of candidate explosives
  - Single fragment survivability test (booster only)
  - Explosive Transfer Reliability tests (limited test series)
  - Review available explosives characterization data
  - Select two best explosive candidates for continued test
  - Armament Section-level FI tests (simulated warheads)
  - All-Up-Round Missile-level FI tests
- Explosive Selection Committee Recommendation

# EXPLOSIVE CANDIDATES

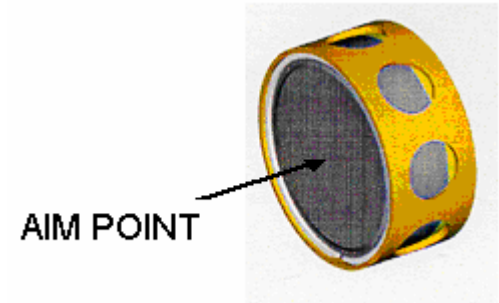


- **CH-6 Baseline**
- **PBXN-5**
- **PBXN-7**
- **PBXN-9**
- **PBXW-128 (Q)**
- **PBXW-11 (Q)**

# SINGLE FRAGMENT IMPACT TEST RESULTS



- Identify the fragment velocity threshold (onset of violent reaction) for each candidate explosive
- PBXN-9, PBXW-11 and PBXW-128 ~ 6000 ft/sec
- CH-6 < 3500 ft/sec



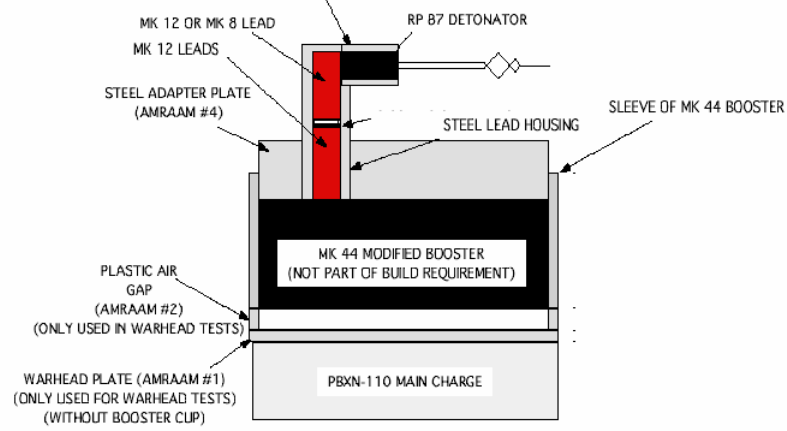
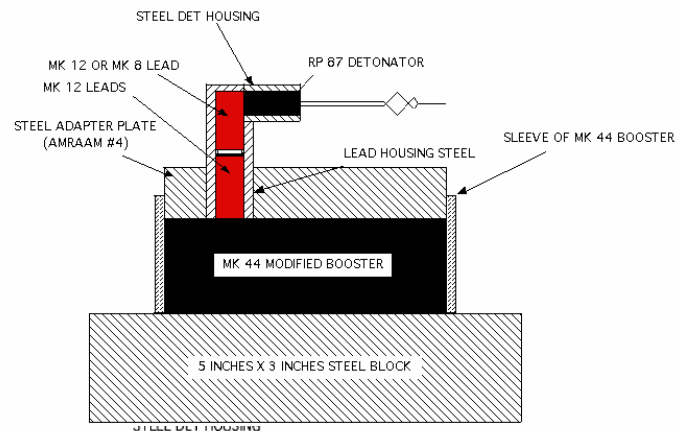
Summary of the Fragment Impact Tests on Various Explosives						
Fragment Velocity Nominal (ft/sec)	Explosive / Reaction Level *					
	CH-6	PBXN-5	PBXN-7	PBXN-9	PBXW-11	PBXW-128
6000	I/II**	I/II	I/II	V, I/II **	V **, I/II**	IV/V?, I/II **
4500	-	I/II **	I/II **	I/II	I/II **	V, I/II**
4000	-	-	I/II	I/II **	V	I/II **
3500	I/II	-	-	-	-	-
* Reaction Levels		I	Detonation			
		II	Partial Detonation			
		III	Explosive			
		IV	Deflagration			
		V	Burning			
"-" No Test Performed						
** Pusher Plate hit the Booster						
? Unknown whether Flyer Plate Impacted Booster (No Witness Plate)						



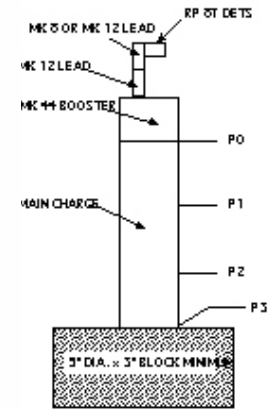


# TEST SET-UP FOR BOOSTER

AMRAAM BOOSTER ASSEMBLY DRAWING  
(BOLT BODY REMOVED FOR CLARITY (DRAWING AMRAAM #3))



AMRAAM ASSEMBLY DRAWING  
(BOLT REMOVED FOR CLARITY)





# Preliminary Transfer Test Results

## Explosive Transfer Tests – Lead / Booster

	PBXN-5	PBXN-7	PBXN-9	PBXW-128	PBXW-11	CH-6
Lead / Booster Pellet Detonation occurred	Yes	Yes	Yes	Yes	Yes	Yes
Average Block Dent Output (in.):	0.218	0.170	0.217	0.205	0.232	0.167

## Explosive Transfer Tests – Booster / Main Charge (PBXN-110)

	PBXN-5	PBXN-7	PBXN-9	PBXW-128	PBXW-11	CH-6
Booster / Main Charge Detonation occurred	Yes	Yes	Yes	Yes	Yes	Yes
PBXN-110 Velocity (mm/ $\mu$ sec): Average	8.58	8.24	8.32	8.26	8.55	8.57
Block Dent Output (in.):*						
Test 1 (MK 8/MK 12)	0.650	0.700	0.640	0.746	0.737	0.675
Test 2 (MK 12 / MK 12)	0.709	0.683	0.699	0.709	0.720	0.724

\*MK 8 and MK 12 leads used to initiate booster as shown



# CHARACTERIZATION DATA FOR CANDIDATE REPLACEMENT BOOSTER EXPLOSIVES

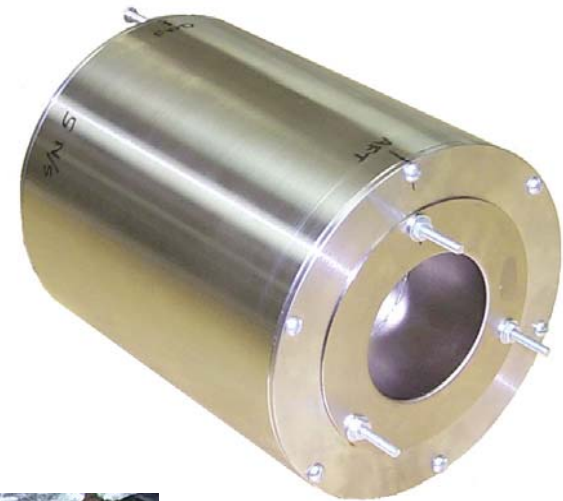
- No further testing of PBXN-9, PBXN-7, and PBXN-5 candidates required.
- PBXW-128 and PBXW-11 selected for continued evaluation

	<b>CH-6</b>	<b>PBXN-5</b>	<b>PBXN-7</b>	<b>PBXN-9</b>	<b>PBXW-128</b>	<b>PBXW-11</b>
Composition (Primary Ingredients)	RDX – 97.5%	HMX – 95%	RDX – 35% TATB - 60%	HMX – 92%	HMX – 77%	HMX – 96%
Impact Sensitivity (50% Height)(cm)	27	36	44-52	34	38.6	25
Friction Sensitivity (lbf)	250	418	> 980	420	> 980	315 (ABL)
Large Scale Gap Test (cards)	306 – 314 Cards	206 Cards	204 Cards	169 – 199 Cards	124 Cards	206 – 238 Cards
VCCT Data	0.015 wall Detonation (□ = 1.65 g/cc)					

# ARMAMENT SECTION-LEVEL FI TESTS



- Simulated hardware differed from actual AMRAAM warheads
  - Only 8.5-inches in length
  - End plates not welded
  - Case not internally broached
- Four test, two fragments per test
- Results unofficially scored as “Deflagration”
  - End plates thrown over 200 ft
  - Up to 85% of bulk explosive recovered



# ALL-UP-ROUND MISSILE-LEVEL FI TESTS

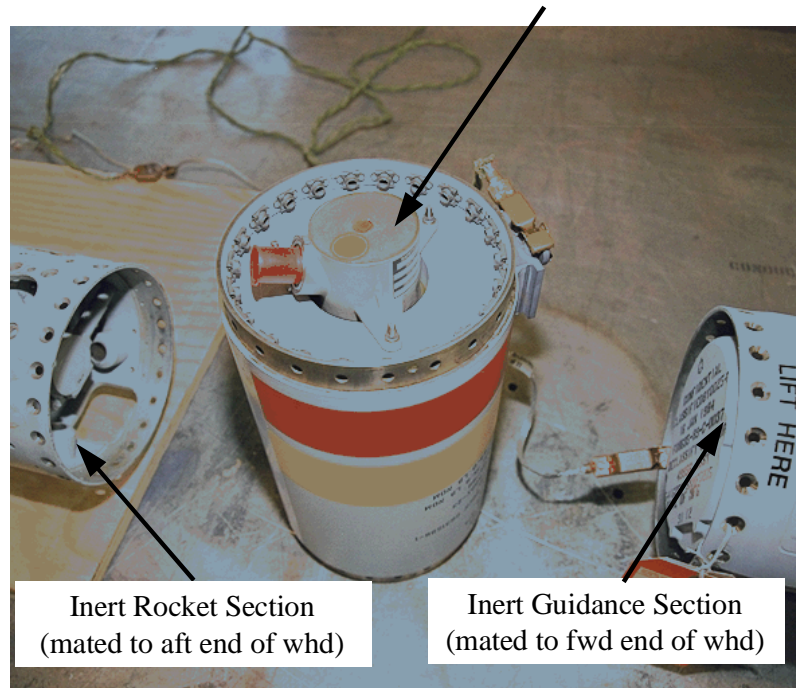
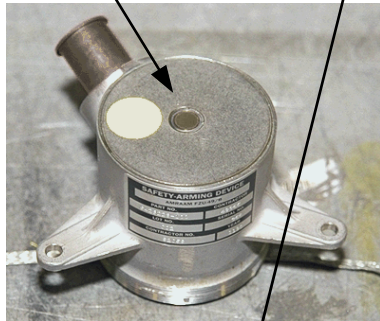


- Fragment Impact Test Hardware

Safety-Arming Device

Booster Pellet

Booster Pellet mounted to the Safety -Arming Device, and secured into the aft end of the AMRAAM warhead.



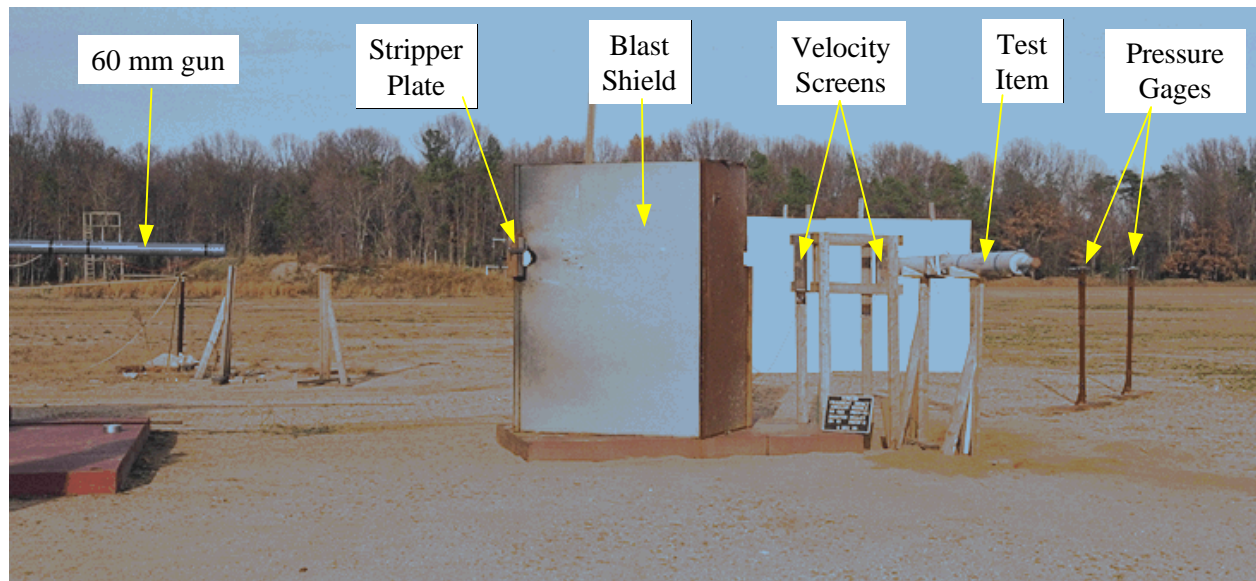
Inert Rocket Section  
(mated to aft end of whd)

Inert Guidance Section  
(mated to fwd end of whd)

# ALL-UP-ROUND MISSILE-LEVEL FI TESTS



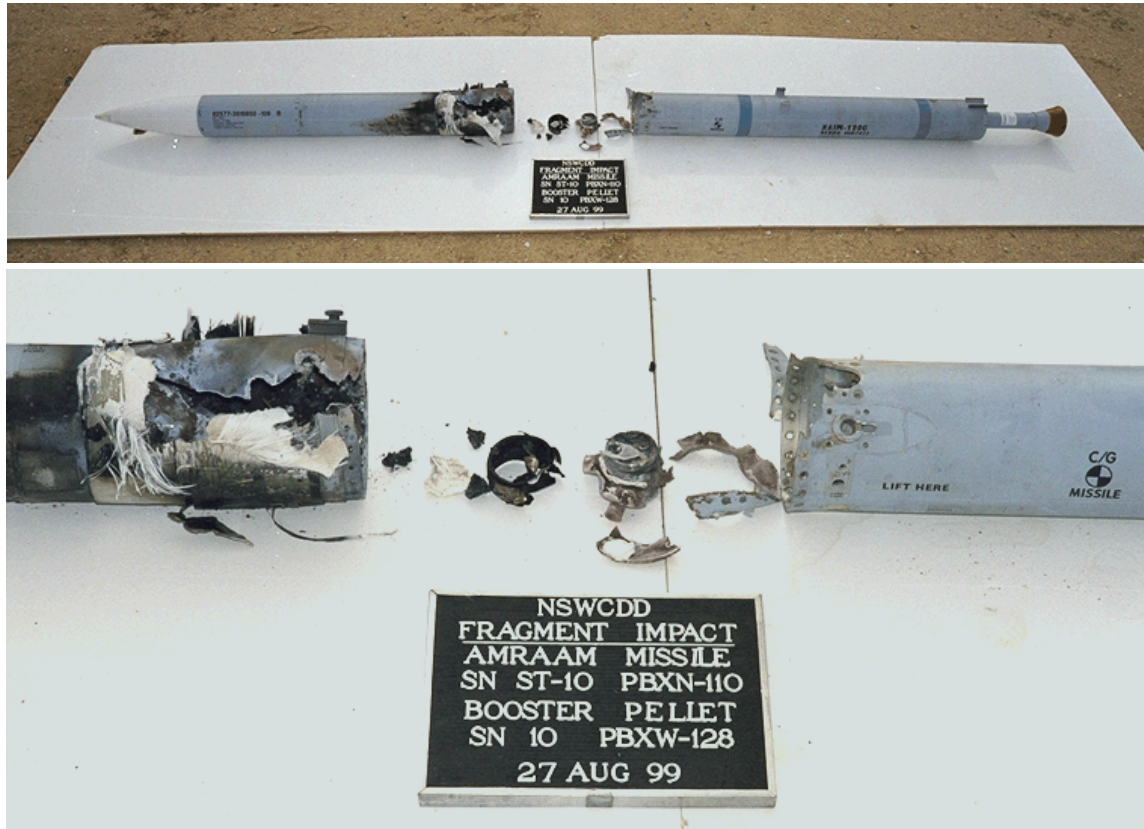
- Fragment Impact Test Setup



# ALL-UP-ROUND MISSILE-LEVEL FI TESTS



- Fragment Impact Test Results (PBXW-128 Booster)

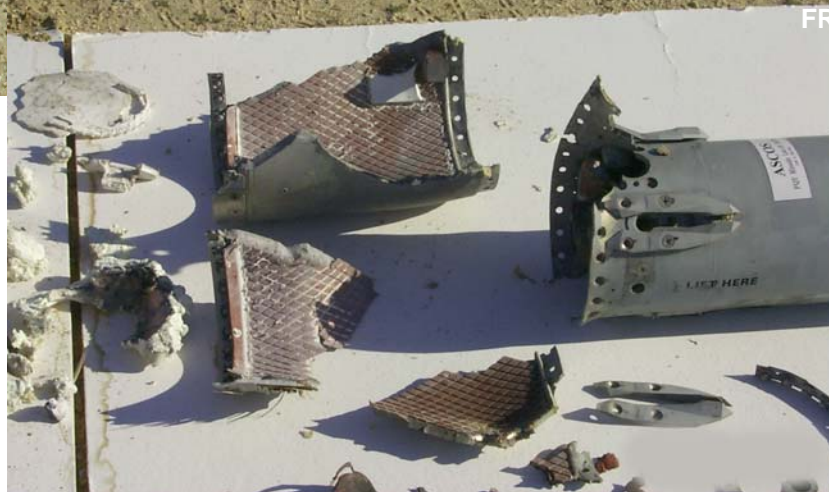


AMRAAM WARHEAD WDU-41/B  
FRAGMENT IMPACT DEMO TEST (8/27/99)  
BOOSTER EXPLOSIVE - PBXW-128



# ALL-UP-ROUND MISSILE-LEVEL FI TESTS

- Fragment Impact Test Results (PBXW-11(Q) Booster)





# ALL-UP-ROUND MISSILE-LEVEL FI TESTS



- All-Up-Round Missile-Level FI Test Results Summary

	EMRTC	NSWCDD	NSWCDD
Date:	12/11/97	8/27/99	12/8/99
Configuration:	Simulated Guidance Section (no internal pressure) Inert Rocket Motor	Guidance Section (internal pressure) Inert Rocket Motor	Guidance Section (internal pressure) Inert Rocket Motor
Test Stand:	Suspended	Platform	Platform
Fragment Qty / Primary Aim Point:	2 Booster (CH-6)	2 Booster (PBXW-128)	2 Booster (PBXW-11)
Fragment Launcher:	Propellant Gun	Propellant Gun	Propellant Gun
Fragment Velocity:	8,197 ft/s	8,400 ft/s	8,200 ft/s
Debris Distance / Wt.:	(Item Detonated)	All debris recovered within 30'  1 Fragment recovered in booster housing @17' / 3-4 oz of explosive recovered remainder burned	All debris recovered within 30'  booster housing broke into several small fragments within 50' / 10% of explosive recovered remainder burned
IM Score:	Type I (Detonation) (NAWCWD OHEB)	Type V (Burning) (NSWCDD IMRB)	Type V (Burning) (NSWCDD IMRB)

# EXPLOSIVE SELECTION COMMITTEE RECOMMENDATION



- Explosive Selection Committee Recommendation: PBXW-11(Q) ( $r = 1.78 \pm 0.03$  g/cc)
  - Little difference in Fragment Impact for PBXW-11 and PBXW-128
  - Improved FI Response over CH-6
  - Possible Improved SCO Response over CH-6
  - PBXW-11 used in SABRE, JSOW, XM 80 Submunition
  - PBXW-128 was not qualified as a booster material and therefore additional testing would be required to ensure it's transfer reliability.
  - Pressed Booster current method used in production of CH-6
  - Improved System FI Response From Type I to Type V
  - Demonstrated PBXW-11 potential to meet System Requirements Based on Preliminary Transfer Tests

# APPROACH



## Phase II: Booster-Level Qualification and Performance Tests

- Environmental and Qualification Tests
- Performance (Explosive Transfer Reliability) Tests
- DOA Diffusion Assessment
- Request PBXW-11(Q) Final (Type) Qualification for use as AMRAAM Booster
- Request Booster Final Hazard Classification

# ENVIRONMENTAL, QUALIFICATION AND PERFORMANCE TEST MATRIX



Test	BOOSTER REQUIREMENTS	WARHEAD REQUIREMENTS
	PBXW-11	PBXN-110 (3" x 6")
Test sample requirements for environmental test		
Units used for environmental tests	40	
Environmental test sequence <sup>1</sup>	5	
Transportation Vibration <sub>1</sub>	5	
Captive Carry and Missile Flight Vibration <sup>1</sup>	5	
14 Day Temperature and Humidity <sup>1</sup>	0	
28 Day Temperature and Humidity	5	
High Temperature Storage	5	
Thermal Shock	5	
1.5 Meter Drop	5	
12 Meter Drop <sup>1</sup>	0	
Jolt <sup>1</sup>	5	
Lead to Environmental Conditioned Booster And Booster to Warhead	16	16
165°F	0	0
Ambient	14	14
- 65 °F	2	2

1. Testing currently required in AS-3427.

2. Dent Output requirement will be determine with this testing.

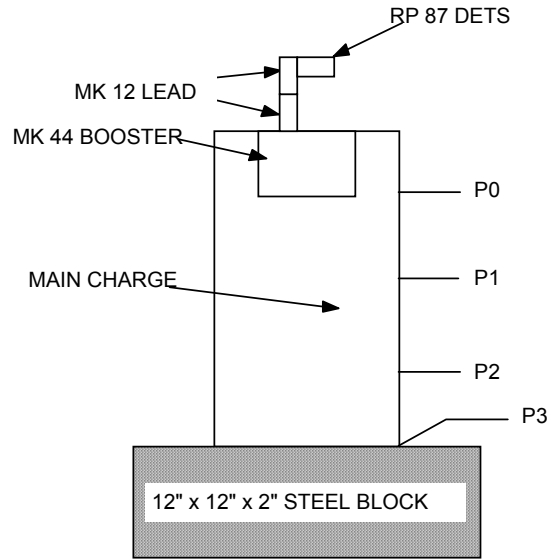
Distribution statement A: Unlimited



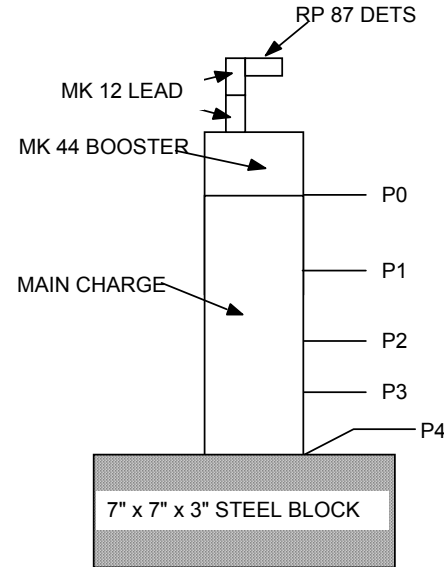
# VARICOMP/VARIDRIVE ASSESSMENT TEST SET-UP FOR BOOSTER



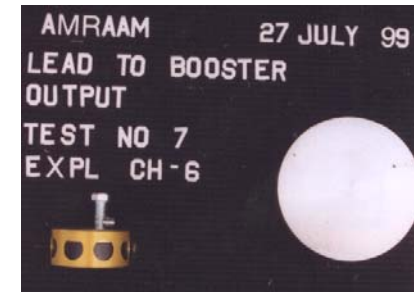
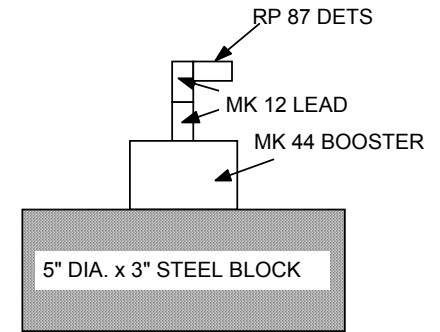
**LEAD TO BOOSTER TO 6" X 8" WARHEAD  
TRANSFER TESTING**



**LEAD TO BOOSTER TO 3" X 6" WARHEAD  
TRANSFER TESTING**



**LEAD TO BOOSTER  
TRANSFER TESTING**





# EXPLOSIVE TRANSFER RELIABILITY TEST RESULTS

Lead - to - Booster Transfer		Booster - to - Stick Warhead Transfer		Booster - to - Simulated Warhead Transfer	
PBXW-11 Density (g/cc)	Mean Dent Output (inches)	PBXW-11 Density (g/cc)	PBXN-110 Warhead Results	PBXW-11 Density (g/cc)	Results
1.78	0.249	1.78	20 for 20 Transfer Functions	1.78	3 for 3 Transfer functions for PBXN-110
1.30	0.148	1.30	3 for 3 Transfer Functions	1.25	3 for 3 Transfer functions for PBXN-110
1.20	0.113	1.20	3 for 3 Transfer Functions	1.20	5 for 5 Transfer functions for PBXN-110
1.10	0.068	1.10	3 for 3 Transfer Functions	1.15	2 for 2 Transfer functions for PBXN-110
		1.00	0 for 3 Transfer Functions	1.20	1 for 2 Transfer Functions with PBXW-128

- VARIDRIVE: Evaluated PBXW-11 at densities from 1.78 g/cc to 1.00 g/cc
- VARICOMP: Evaluated PBXW-11 (density 1.20 g/cc) to PBXW-128 (77% HMX)
- Minimum average dent specified > 0.200" with no value below 0.160"
- Reliability of 99.99998% with a 95% Confidence level ( $\rho = 1.78 \pm 0.03$  g/cc)

# DOA DIFFUSION ASSESSMENT



**• Accelerated aging tests were conducted to evaluate the effectiveness of various sealant materials in preventing Di-Octyl-Adipate (DOA) diffusion.**

- Test Series 1: 200°F for 16 weeks, boosters assembled at NSWC
  - No sealant applied
  - DOA diffusion observed
- Test Series 2: 160°F for 22 weeks, boosters assembled at NSWC
  - Various sealant applied
  - Current sealant (Sylgard 170) should prevent DOA diffusion
- Test Series 3: 160°F for 2 weeks, boosters assembled by the manufacturer
  - Current sealant (Sylgard 170) applied using current process

**Current booster sealant material and processes will prevent DOA diffusion**

# APPROACH



## Phase III: Missile-Level Qualification and Performance Tests

- Raytheon Vendor Qualification Tests
- Environmental Tests
  - Aging Tests
  - Missile-Level Vibration Tests
- Performance Tests
  - Booster Function Tests
  - Warhead Arena Tests
- All-Up-Round Level IM (FCO, FI) Tests
- Request Final (Type) Qualification for AMRAAM with Mk 80 Booster
- Request Final (Hazard) Classification for AMRAAM with Mk 80 Booster



# RAYTHEON VENDOR QUALIFICATION TEST MATRIX



- The Current booster vendor, Reynolds Systems, successfully completed all vendor qualification tests
  - Environmental, Qualification and Performance Tests (30 Units)

TEST	BOOSTER REQUIREMENTS
Transportation Vibration (+145°F)	15
Transportation Vibration (-40°F)	15
Temperature & Humidity	30
Captive Flight % Missile Flight Vibration (+170°F)	15
Captive Flight % Missile Flight Vibration (-50°F)	15
Radiographic Inspection	30
40-Foot Droop	3
Jolt	2
Function and Output	25

# ENVIRONMENTAL TESTS



- **Aging tests (160°F (71°C), 16 weeks) conducted by booster vendor, Reynolds Systems**
  - Mk 44 Mod 1 Boosters (2)
  - Mk 80 Boosters (15)
  - PBXW-11(Q) Pellets (5)
  - No anomalies
- **Vibration tests conducted by NSWC Dahlgren Division**
  - Vibration to worst-case missile levels measured during captive carriage
    - F-15, F-16, F/A-18C/D/E/F
  - Mk 44 Mod 1 Booster (1)
  - Mk 80 Booster (2)
  - No anomalies



# PERFORMANCE TESTS

- **Booster Function Tests (42)**
  - o Mk 80 Boosters were function tested as part of the vendor qualification (25 units) and aging test (15 units) efforts.
  - o Mk 80 Boosters were function tested as part of the missile-level vibration tests (2 units)
  - o All test results demonstrate that the Mk 80 meets or exceeds the performance requirements of the current Mk 44 Mod 1 Booster
- **Warhead Arena tests (2) were conducted by Raytheon at NTS**
  - o WDU-41/B Warheads configured with SAF and Mk 80 Booster
  - o Both tests resulted in the warhead detonation
  - o Warhead performance was unchanged

# ALL-UP-ROUND LEVEL IM TESTS



- **Fragment Impact Test (1)**

- o The first warhead FI test (Mk 80 Booster) was previously completed during Phase I
- o A second warhead FI test (Mk 80 Booster) was required for official score
  - This test was also conducted at NSWC Dahlgren (May 03)
  - The warhead was configured with a PBXW-11(Q) Booster and confined by an adjoining Guidance Section and Inert Rocket Motor
- o **Test scored by NSWC IMRB as Type V, Burning reaction**



# FRAGMENT IMPACT TEST RESULTS

## (Baseline vs. Mk 80 Booster)



	EMRTC	NSWCDD	NSWCDD
<b>Date:</b>	12/11/97	12/8/99	5/13/03
<b>Configuration:</b>	Simulated Guidance Section (no internal pressure) Inert Rocket Motor	Guidance Section (internal pressure) Inert Rocket Motor	Guidance Section (internal pressure) Inert Rocket Motor
<b>Test Stand:</b>	Suspended	Platform	Platform
<b>Fragment Qty / Primary Aim Point:</b>	2 Booster (CH-6)	2 Booster (PBXW-11)	2 Booster (PBXW-11)
<b>Fragment Launcher:</b>	Propellant Gun	Propellant Gun	Propellant Gun
<b>Fragment Velocity:</b>	8,197 ft/s	8,200 ft/s	8,333 ft/s
<b>Debris Distance / Wt.:</b>	Item Detonated	All debris recovered within 30' booster housing broke into several small fragments within 50' / 10% of explosive recovered, remainder burned	All debris recovered within 5' Booster remained attached to warhead. Most of booster recovered intact. Most of the PBXN-110 consumed
<b>IM Score:</b>	Type I (Detonation) (NAWCWD OHEB (1))	Type V (Burning) (NSWCDD IMRB (2))	Type V (Burning) (NSWCDD IMRB (3))

# ALL-UP-ROUND LEVEL IM TESTS



## • Fast Cook-off (1)

- o Test required to verify that warhead FCO performance is not degraded
  - Current warhead FCO score is a Type IV, Deflagration
- o This test was conducted at NSWC Dahlgren (May 03)
  - The warhead was configured with a PBXW-11(Q) Booster and confined by an adjoining Guidance Section and Inert Rocket Motor



# FAST COOK-OFF RESULTS



## MASS AND RANGE OF RECOVERED DEBRIS

ITEM	MASS (lb)	RANGE (ft)	HAZARDOUS FRAGMENT
RADOME SECTION	6.55	75	YES
STAINLESS STEEL BAND	0.19	110	NO
STAINLESS STEEL BAND	0.19	144	NO

- Test scored by the NSWC IMRB as Type VI, Deflagration reaction
  - Radome debris distance is not attributed to booster performance
- **The Mk 80 Booster will not degrade warhead FCO performance**



# SUMMARY

- The AMRAAM Alternate Booster Explosive Concept Demonstration and Transition programs have been successfully completed, identifying and qualifying a new explosive PBXW-11(Q), for use in the AMRAAM warhead booster
- The “Mk 80 Mod 0” nomenclature has been assigned to the new booster. The new booster hardware is unchanged from that of the current Mk 44 Mod 1 Booster
- The Mk 80 Mod 0 Booster is a suitable form-fit-function replacement for the Mk 44 Mod 1 Booster currently used in the AMRAAM WDU-41/B Warhead
- The Mk 80 Mod 0 Booster has been proven, through extensive testing, to improve the Fragment Impact performance of the AMRAAM warhead (from a “Detonation” to a passing “Burning” reaction). The Mk 80 Mod 0 Booster will not degrade current AMRAAM warhead Fast Cook-off performance (a “deflagration”)
- Final (Type) Qualification has been granted at booster and system levels
- Final Hazard Classification has been granted at booster and system levels
  - Proper Shipping Name: Booster [Without Detonator], UN0042
  - Product Designation: Booster, Assembly, Mk 80 Mod 0
  - NSN: 1336-01-515-0117
  - UN Classification Code: 1.1d
  - EX Letter: EX2004030001



# REFERENCES



1. NSWCDD Ltr 8010.1 Ser G707/028 of 28 Feb 00, *Insensitive Munitions Review Board (IMRB) Meeting on the AMRAAM Warhead Test Results for IM Mitigation Proposal*
2. L.J. Montesi, K. E. Alexander, *Characterization of PBXW-11 Pressed Explosive*, Naval Surface Warfare Center, Indian Head Division, IHTR 1827, 8 April 1996.
3. P. F. Spahn, L. J. Montesi, *Detonation Transfer Reliability: VARICOMP and VARIDRIVE Using Energy Fluence and the Logistic Analysis*, Naval Surface Warfare Center, Indian Head Division, IHTR 2292, 25 September 2000.
4. IHDIV/NSWC Ltr 8000 Ser 4440/04-043 of 17 Mar 04, *Request for Final (Type) Qualification of PBXW-11(Q) in the Mk 80 Mod 0 Fuze Booster*
5. L. J. Montesi, J. Mackey, C. Peletski, *PBXN-9/PBXN-5 Dioctyl Adipate diffusion Studies*, Naval Surface Warfare Center, Indian Head Division, IHTR 2237, 11 February 2000.
6. Reynolds Systems Inc. Ltr of 16 Jan 04, *Mk 80 Fuze Booster P/N 2003AS500 Accelerated Aging Test by Reynolds Systems Inc.*
7. NAWCWD China Lake Ltr 8020 Ser 473300D/3584, *Ordnance Hazards Evaluation Board (OHEB) Meeting Minutes of 18 June 1998*
8. NSWCDD Ltr 8010.1 Ser 707/243 of 30 Jul 03, *Insensitive Munitions Review Board (IMRB) Meeting on the AMRAAM Warhead (With Mk 80 Mod 0 Booster) Fast Cook-off and Fragment Impact Test Results*
9. NAVSEA Ltr 8020 Ser N611/586 of 28 Apr 04, *Final (Type) Qualification of PBXW-11 in the Mk 80 Mod 0 Fuze Booster*
10. IHDIV/NSWC (Yorktown Det) Ltr 8020 Ser 2410B/365 of 4 May 04, *PBXW-11 Final (Type) Qualification Nomenclature Assignment of PBXN-11*
11. NAVAIR PMA-268 8020 AIR-4.1.1.6/AMRAAM of 5 Apr 04, *Request for Final (Type) Qualification of the Mk 80 Mod 0 Fuze Booster for use in the AMRAAM WDU-41/B Warhead*
12. NAVSEA Ltr 8020 Ser N611/706 of 26 May 04, *Final (Type) Qualification of Energetic Material Used in the AMRAAM WDU-41/B Warhead*