



Development and Manufacture of an Insensitive Composition B Replacement Explosive IMX-104 for Mortar Applications

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Briefing Outline

- Program Goals & Background
- Formulation Development
- Material Characterization
 - IM Testing (IMX-104 in 81mm and 120mm Mortar)
 - IMX-104 Qualification Status
- IMX-104 Large Scale Manufacturing
- Concluding Remarks
- Acknowledgements

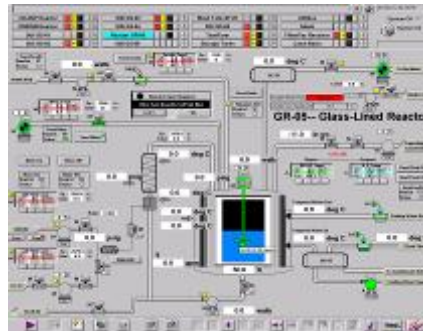
Program Goals & Background

- PM-Mortars funded PAX-21 Product Improvement Program (PIP) for the 60mm Mortar with the primary goals:
 - Replace AP in PAX-21 (environmental issue)
 - Achieve PAX-21 or better performance
 - Achieve PAX-21 or better IM Response
- Secondary goal - utilization of ingredients manufactured on production scale at Holston in these new formulations:-
 - RDX, HMX (conventional Holston ingredients)
 - DNAN, NTO, TATB, HBD NQ (new ingredients)
- Utilizing manufacturing technologies that were a good-fit for the U.S. Industrial base
 - Traditional Melt-pour processing
 - Large capacity equipment
 - Recrystallization
 - Incorporation, drying & flaking of product
 - Dry Fluid Energy Milling of ingredients as required (a contributing technology)



In insensitive Ingredients

- DNAN, NTO and NQ - inherently less sensitive than traditional high explosives and melt base ingredients
- Selected as materials for scale-up and production at Holston because of their perceived benefits and adequate suitability with the existing infrastructure
- Now STANDARD PRODUCTS from Holston Army Ammunition Plant
 - Manufactured in Agile Facility at Holston



In insensitive Explosive Formulations

- Development Efforts resulted in several new formulations, the most promising of which include:
 - IMX-101** (formerly OSX-CAN) for Artillery Ammunitions
 - Achieved the best IM results in full-scale ammunition trials:-

IM Test:	Fast Heating	Slow Heating	Bullet Impact	Fragment Impact	Sympathetic Detonation	Shaped Charge Jet Impact
Passing Criteria	V	V	V	V	III	III
M795 Baseline (TNT)	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
IMX-101	PASS	PASS	PASS	PASS	PASS	PASS Ø 81mm

- IMX-101 is QUALIFIED by the U.S. Army as a main charge explosive and TNT replacement. Type (system) qualification evaluation for Artillery Ammunition is completed
- IMX-104 (formerly OSX-7)** (DNAN, RDX, and NTO) for Mortars
 - Qualified by the U.S. Army as a main charge explosive and Composition B replacement
 - Type (system) qualification testing will be performed in FY 2012
- PAX-48 (formerly OSX-8)** (DNAN, HMX, and NTO) for Mortars and Direct-Fire Ammunition
 - Qualified by the U.S. Army as a main charge explosive for the 120mm IM HE-T Ammunition

Formulation Development - Overview

- Two formulations of greatest interest to OSI Customers
 - IMX-104 (DNAN, NTO and RDX based)
 - PAX-48 (DNAN, NTO and HMX based)
 - Both formulations possess energetic performance similar to Composition B

Typical Properties of IMX-104 and PAX-48 Versus Traditional Mortar Fillings

Material	TMD (g/cc)	VOD (% Comp B)	LSGT (50% Card Gap)	Reference	Scale of Manufacture	DSC MP / Exotherm Onset (C)	Efflux Viscosity (sec.) @ 96 C
TNT	1.65	84	133	MSIAC	1,200 – 1,500 LB Full Production Scale	-	-
Comp B	1.76	100	207	LLNL/NOL		80 / 215	-
PAX-21	1.72	83	161	UTEC/ARDEC		89 / 193	< 10
IMX-104	1.73	95/92 *	118	OSI/GD-OTS Canada*		89 / 213	< 10
PAX-48	1.76	93/91 *	110	OSI/GD-OTS Canada*		93 / 231	< 10

- Both are proving worthy candidates for evaluation in IM Mortar applications
 - Undergoing evaluation in USA and Europe
 - IMX-104 & PAX-48 both achieved U.S. Army Qualification status (as explosive material) in the U.S.

Formulation Development – Performance Comparison

- IMX-104 and PAX-48 designed to have performance similar to Composition B



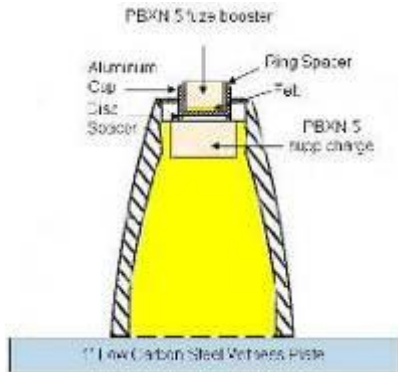
IMX-104



PAX-48



Comp B



120mm mortar ogive (initiation test set up)



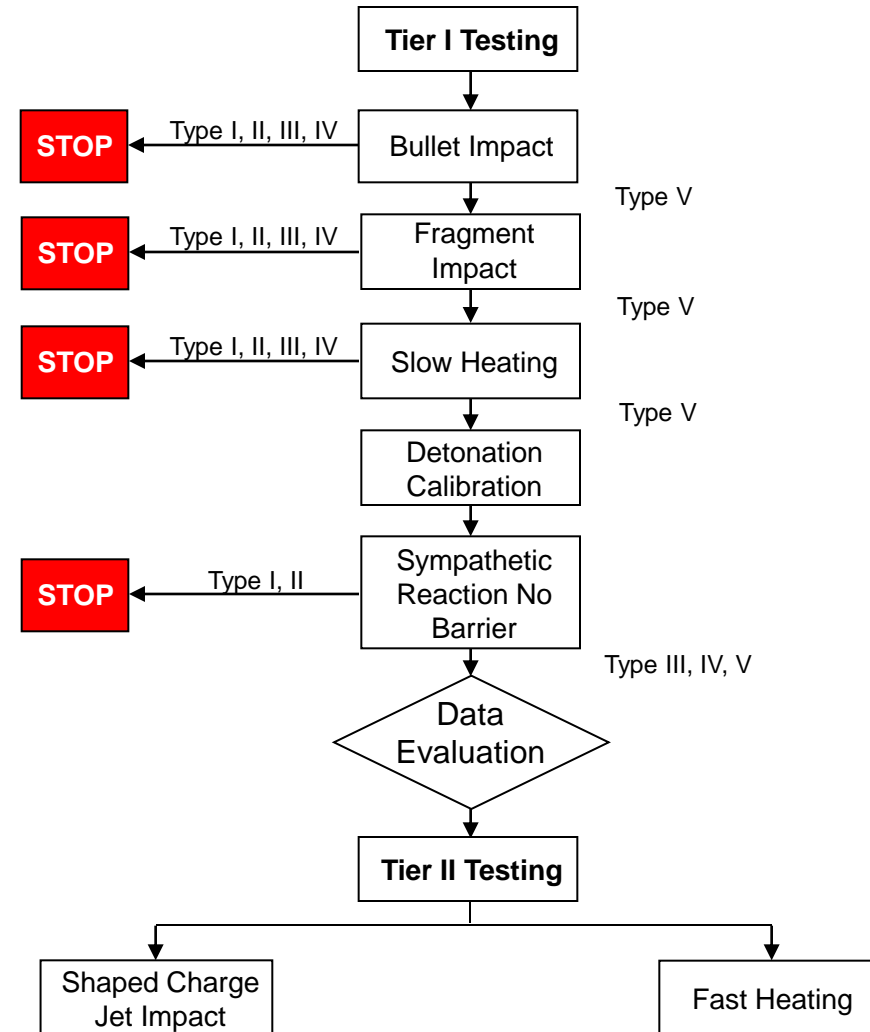
Formulation Development - Large Scale Manufacturing Process Development

- IMX-104 & PAX-48
 - Large scale manufacture in Holston production equipment (1200 lb. batch)
 - Material supplied to PM-CAS for loading into mortars for IM Testing, and to General Dynamics for the 120mm IM HE-T Program
 - Both formulations successfully scaled up with adequate processability



IM Assessment Testing in Mortar Ammunitions

- US ARMY PM-CAS Common Low-cost IM Explosive Program (CLIMEx) Phase 2
 - Evaluation of IM explosive candidates as Comp B replacement in 81/120mm Mortar
 - IMX-104 and PAX-48 selected as OSI's candidates
 - Also evaluated were candidates from other manufacturers including melt-pour, cast-cure and pressable explosives



IM Assessment Testing – Baseline Test Results



IM Test:	Fast Heating	Slow Heating	Bullet Impact	Fragment Impact	Sympathetic Detonation	Shaped Charge Jet Impact
Passing Criteria	V	V	V	V	III	III
60mm (Comp-B/PAX-21)	II V**	III II**	V	III	(I)*	(I)*
81mm (Comp-B)	(II)*	(II)*	(III)*	(III)*	(I)*	(I)*
120mm (Comp-B)	II	I	I	I	(I)*	(I)*

* Assessment -- not tested

** with PAX-21 and Intumescent Coating

60mm



0.8 lb (1.8kg) PAX-21/Comp B

81mm



2.0 lb (4.4kg) Comp B

120mm



6.6 lb (14.5kg) Comp B

Results and images courtesy of PM-CAS

IMX-104 IM Test Results (81/120 mm Mortar) – Summary



BI

Bullet Impact 81/120mm (TYPE V – 7.62mm)



FI

Fragment Impact 120mm (TYPE V)



FH

Fast Heating 81mm (TYPE V)



Sympathetic Detonation 81/120mm (TYPE III)



SD



Slow Heating 81/120mm (TYPE V)



SH

Images courtesy of PM-CAS

IMX-104 IM Test Results - Summary



IM Test:	Fast Heating	Slow Heating	Bullet Impact	Fragment Impact	Sympathetic Reaction	Shaped Charge Jet Impact
Passing Criteria	V	V	V	V	III	III
81mm (Comp-B) Baseline	(II)*	(II)*	(III)*	(III)*	(I)*	(I)*
81mm (IMX-104)	V	V	12.7mm 7.62mm IV V	8300 ft/s 6000 ft/s III IV	III	I
120mm (Comp-B) Baseline	II	I	I	I	(I)*	(I)*
120mm (IMX-104)		V	IV	V	III	

- Engineering IM Tests in the M934A1 120mm Mortar and M821A2 81mm Mortar with IMX-104 show significant improvement in IM properties over baseline Comp B
- IMX-104 selected as the prime candidate as an IM Comp. B replacement for Mortar Ammunitions for the US ARMY

* Assessment -- not tested

IMX-104 Material Qualification Status

- IMX-104 material qualification began in late 2009
- Follow protocols as per NATO Allied Ordnance Publication AOP-7 Qualification Procedures for the United States
- All tests including accelerated aging are now completed and PASS ratings achieved across the board
- Test results presented to the US DOD Energetic Material Qualification Board (EMQB) in June 2011
 - Material qualification granted



IMX-104 loaded Mortars Insertion Schedule

- IMX-104 type qualification currently in progress
 - 81mm mortars
 - Extensive evaluation testing including
 - IM System Tests
 - Environmental/Aging Tests
 - Gun Launch Survivability Tests
 - Range and Accuracy
 - Lethality / Fragmentation / Initiation

End Item	Current Main Charge Explosive	IM Main Charge Explosive	Project Start Date	ECP Date
60mm Mortar (M720A1/M768/M888)	PAX-21	IMX-104	2007	FY 2013
81mm Mortar (M821A2/M889A1/ M889A2)	Composition B	IMX-104	2007	FY 2012
120mm Mortar (M933A1/M934A1)	Composition B	IMX-104	2007	FY 2013

IMX-104 Large Scale Manufacturing Overview

Load Ingredients (DNAN, NTO, RDX)



Melt and Mix

Cast onto flaker belt



Molten IMX-104

**Molten IMX-104
in thin strip**

Cool/solidify and break-up



**IMX-104 flakes
(Final Product)**

Pack and ship



IMX-104 Manufacturing Process Development

- Processing Parameters identification
 - Processing temperatures at various stages
 - Ingredient Feed Rate & Order of Addition
 - Use of dry/wet ingredients
 - Final Incorporation (mixing) Time
 - Agitator Speed
- Material Processability indicated by Efflux Viscosity and consistent Product Homogeneity
 - Composition, sensitivity and other physical/chemical properties testing
- Close interaction with ARDEC EM and LAP Producibility Teams
- Continuous Improvement and Process Optimization



IMX-104 Manufacturing Process Summary

- Current batch size over 1300 lb (> 600 kg)
- Over 90,000 lb (> 41000 kg) of IMX-104 had been manufactured at HSAAP
 - Support US ARMY Mortar Loading Trial and Qualification
 - Round-the-clock operation
- Although process is relatively young, it can be considered as robust and repeatable
- Process optimization planned for FY 2012
 - Design of Experiment technique to evaluate various process parameters
 - Reduce process cycle time to lower overall product cost
 - Collaborate with Loading Facility in the evaluation of suitability in loading operation

Concluding Remarks

- A NEW GENERATION of IM melt-pour explosives now available
 - IMX-104 demonstrated excellent IM properties over Composition B
- Low-cost replacement for Composition B
- Reduced shock sensitivity vs. Composition B (and PAX-21)
- Ingredients readily available and manufactured at Holston
- Robust large scale manufacturing process for IMX-104
- Viable candidate for common fill across all mortar sizes
 - Insertion for 81mm by FY 2012, 60mm and 120mm mortar by FY 2013
- Achieved significant IM improvement over current munitions
- Significant National and International interest
 - Insensitive Composition B replacement in other weapon systems

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