



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

2010 Insensitive Munitions & Energetic Material Technology Symposium

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Briefing Outline

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

Program Goals & Background

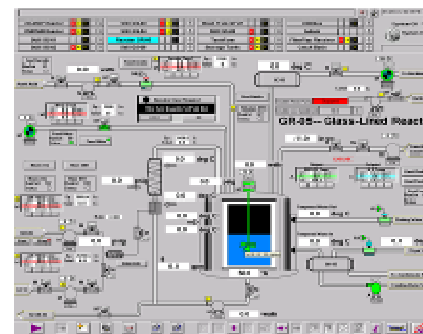
- Program began as part of a PM-Mortars funded PAX-21 Product Improvement Program (PIP) for the 60mm Mortar with the initial goals:
 - Replace AP in PAX-21 (environmental issue)
 - Achieve PAX-21 or better performance
 - Achieve PAX-21 or better IM Response
- A secondary goal of OSI was to use ingredients manufactured on Production scale at Holston in these new formulations:-
 - RDX, HMX (conventional Holston ingredients)
 - DNAN, NTO, TATB, HBD NQ (new ingredients)
- And to use 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)



*NDIA IMEM Conferences – details available from author upon request

Program Goals & Background (cont.)

- DNAN, NTO and TATB - 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 benefit to the ammunition community
- Now STANDARD PRODUCTS from Holston Army Ammunition Plant
 - Manufactured in Agile Facility at Holston



Program Goals & Background (cont.)

- 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:	FCO	SCO	BI	FI	SD	SCJI
Passing Criteria	V	V	V	V	III	III
M795 Baseline (TNT)	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
IMX-101	PASS	PASS	PASS	PASS	PASS	50mm PASS RPG PASS

- IMX-101 is QUALIFIED by U.S. Army as a main charge explosive. Type (system) qualification evaluation for Artillery Ammunition is currently on-going
- IMX-104 (formerly OSX-7)** (DNAN, RDX, and NTO) for Mortars
 - Presently undergoing evaluation for use in Mortar Ammunition
- PAX-48 (formerly OSX-8)** (DNAN, HMX, and NTO) for Mortars and Direct-Fire Ammunition
 - Presently QUALIFIED by U.S. Army for the 120mm HE-T Ammunition

*Refer to NDIA IMEM Symposium, 2007 & 2009 for details on IMX-101

Recent Developments – Most Promising Comp. B Replacement Formulations

- R&D Efforts are now completed
- 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 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	98	118	OSI		89 / 213	< 10
PAX-48	1.76	96	110	OSI		93 / 231	< 10

- Both are proving worthy candidates for evaluation in IM Mortar applications
 - Undergoing evaluation in USA and Europe
 - IMX-104 Undergoing U.S. Army Qualification in the U.S.

Recent Developments – Most Promising Comp. B Replacement Formulations

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



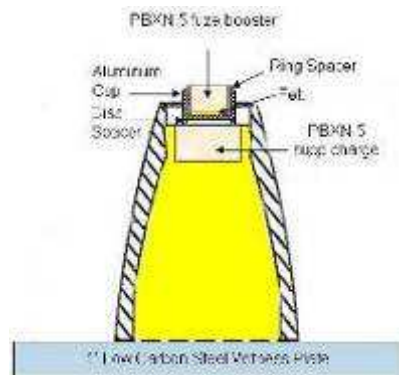
IMX-104



PAX-48



Comp B



120mm mortar ogive
(initiation test set up)



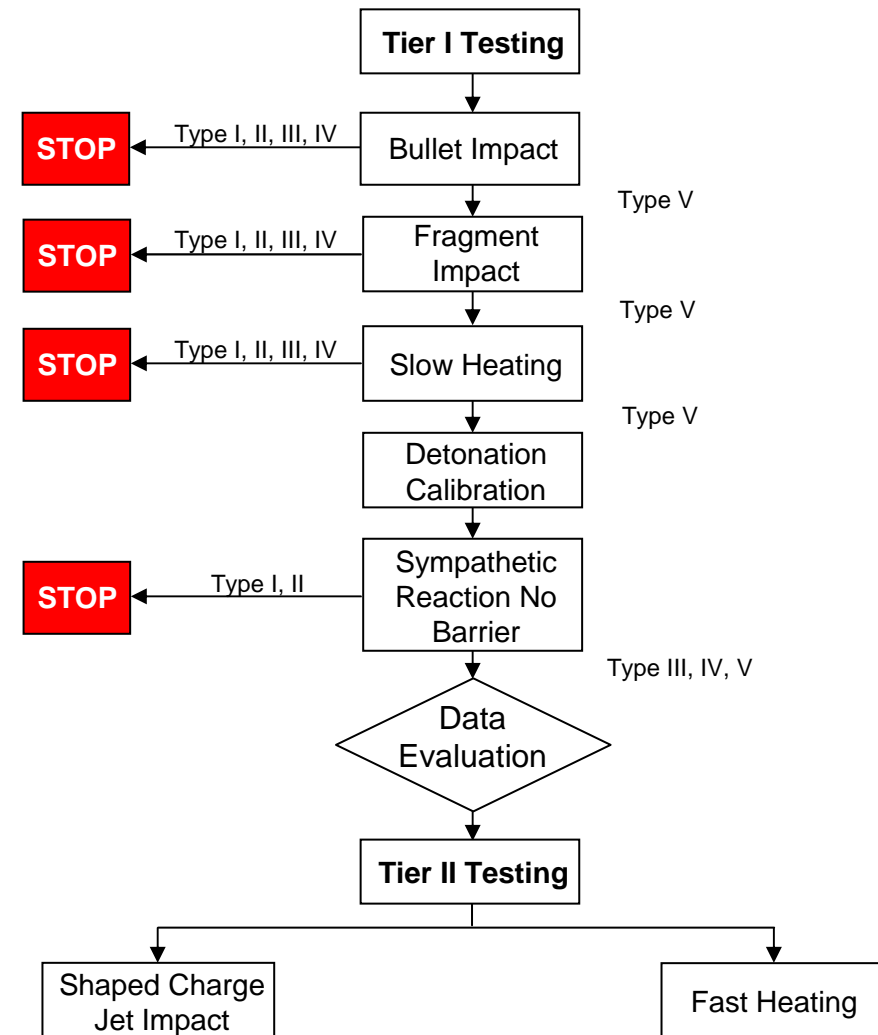
Recent Developments - Large Scale Manufacturing Process Development

- 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 HE-T Program
 - Both formulations successfully scaled up with adequate processability

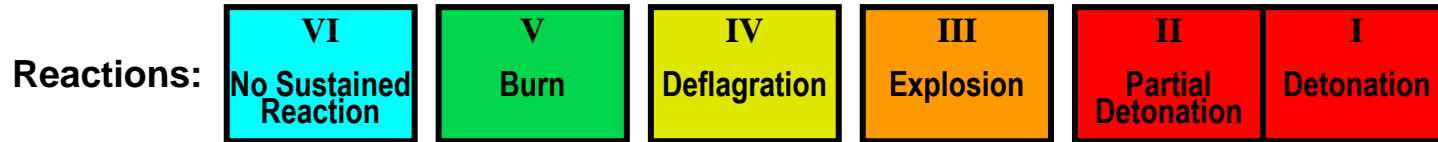


IM Assessment Testing in Mortar Ammunitions

- 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:	FH	SH	BI	FI	SD	SCJI
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



SH

Slow Heating 81/120mm (TYPE V)



Images courtesy of PM-CAS

IMX-104 IM Test Results - Summary

Reactions:

VI No Sustained Reaction	V Burn	IV Deflagration	III Explosion	II Partial Detonation	I Detonation
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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 IV 7.62mm V	8300 ft/s III 6000 ft/s 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

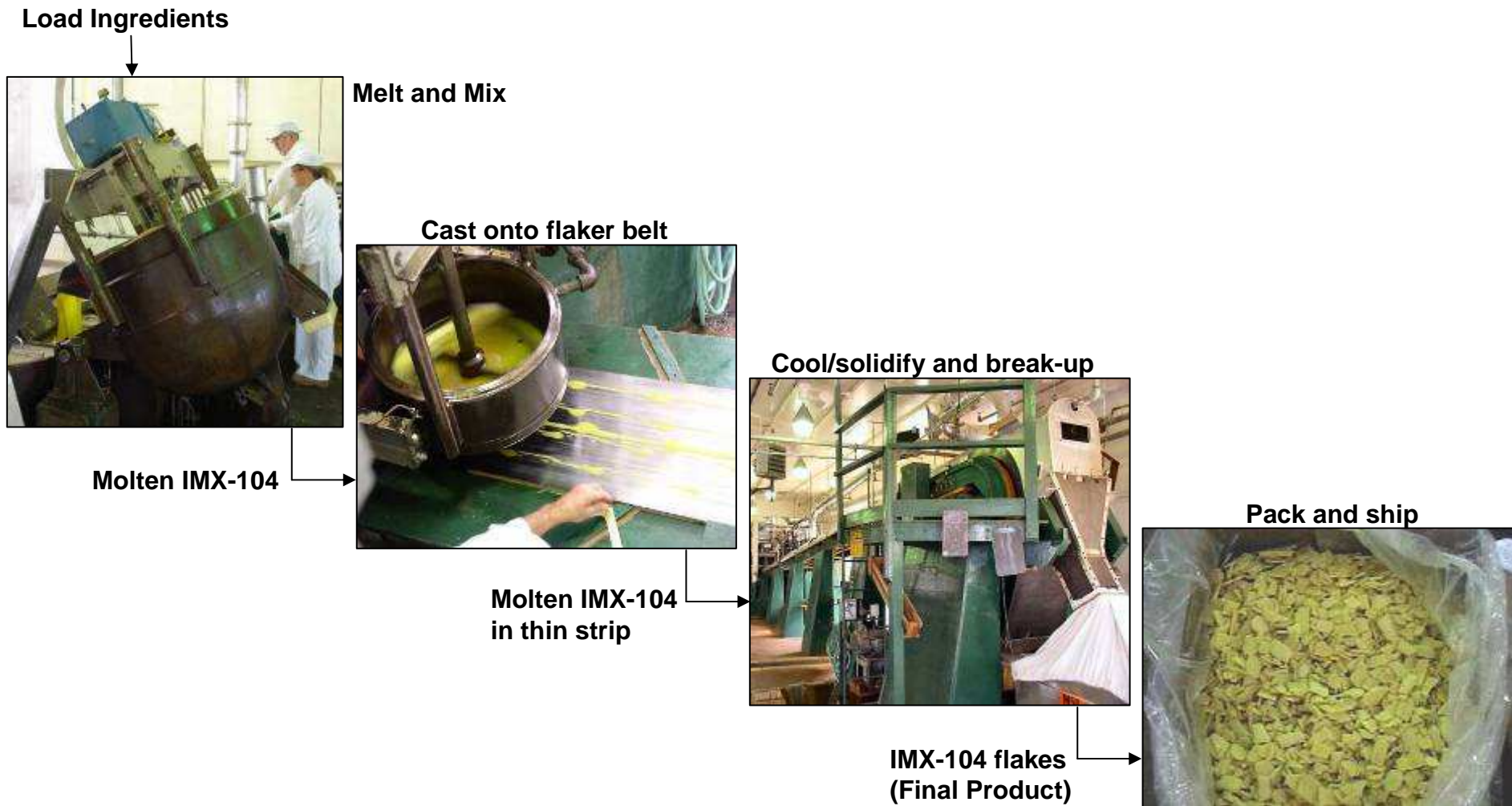
IMX-104 Material Qualification Status

- IMX-104 material qualification began in late 2009
- Follow protocols as per NATO Allied Ordnance Publication AOP-7 Qualification Procedures for the United States
 - Impact Sensitivity ✓
 - Shock Sensitivity ✓
 - Friction Sensitivity ✓
 - Electrostatic Sensitivity ✓
 - Ignition Sensitivity ✓
 - Thermal Stability ✓
 - Critical Temperature Self-Heating ✓
 - Chemical Compatibility (main charge and mortar components) ✓
 - Toxicity Evaluation ✓
 - Detonation Velocity ✓
 - Critical Diameter ✓
 - Exudation and Growth ✓
 - AGEING PROPERTIES (0, 3, 4, 6, 8 and 12 months)
✓ ✓ ✓ ✓ ✓ ✓ ✓

IMX-104 loaded Mortars Insertion Schedule

End Item	Current Main Charge Explosive	IM Main Charge Explosive	Project Start Date	ECP Date
81mm Mortar (M821/M889)	Composition B	IMX-104	2007	2011
60mm Mortar (M720A1)	PAX-21	IMX-104	2007	2011
120mm Mortar (M933A1/M934A1)	Composition B	IMX-104	2007	2012

IMX-104 Large Scale Manufacturing Overview



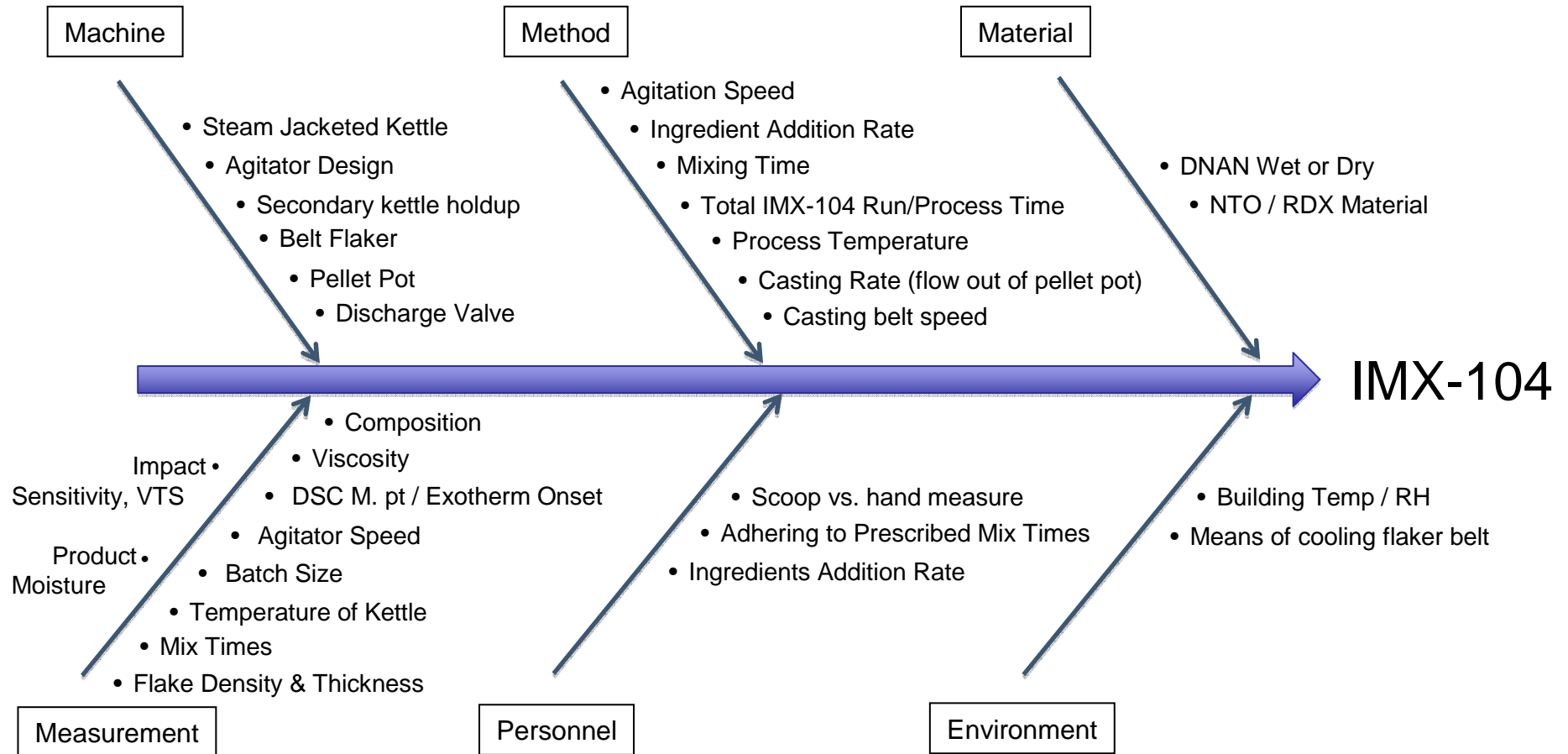
Images shown are from the PAX-21 production

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 Producibility Parameters Considered



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 opportunities
 - 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. Comp 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 60mm & 81mm by 2011, 120mm mortar by 2012
- Capable of achieving full IM Compliance in Mortar Ammunition
 - Requires system integration, not necessarily a drop-in replacement
- Significant National and International interest
 - IMX-104 Undergoing Qualification by U.S. Army

Acknowledgement

- RDECOM-ARDEC
 - Mr. P. Vinh, Mr. A. Di Stasio, Ms. L. Zhao
- PM CAS / PM Mortars
 - Mr. J. Rutkowski, Mr. P. Samuels, Mr. C. Patel, Mr. B. Kuhnle
- BAE SYSTEMS OSI
 - Mr. A. Carrillo, Mr. P. Lucas, Dr. D. Price, Mr. M. Hathaway, Mr. E. LeClaire, Ms. L. Hale, Mr. B Schreiber, Ms. D. Bowyer
 - Plant Operators in the Explosive Finishing Area
- NTS Camden
 - Mr. D. Mann, Mr. M. Brian