A MODERNIZED IM MELT POUR EXPLOSIVE MANUFACTURING FACILITY AT HOLSTON ARMY AMMUNITION PLANT

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ABSTRACT

BAE SYSTEMS Ordnance Systems Inc. (OSI) had been involved in the development and manufacturing of melt pour explosive formulations for consideration in the U. S. Army's selection process for a common Insensitive Munition (IM) explosive fill for artillery and mortar ammunitions. IMX-101 and IMX-104, both of them DNAN based melt pour explosives, had been selected as IM explosive fill to replace TNT and Composition B for the 155mm M795 projectile and mortar rounds of all calibers' respectively.

To date, over 2 million pounds of these Insensitive Melt-Cast Explosives has already been manufactured successfully in full production scale at Holston Army Ammunition Plant (HSAAP) in support of all material and system qualification efforts.

As the demands for these Insensitive Melt Pour Explosives increases, a State-of-the-Art IM Melt Pour Explosive Manufacturing Facility had been constructed at HSAAP to further expands the manufacturing capacity of IM Melt Pour explosive.

The OSI / ARDEC / PM-CAS team had successfully executed several process development and product qualification programs in order to certify the Modernized IM Melt Pour Explosive Manufacturing Facility as a suitable venue to manufacture IMX Products. The successful execution of these projects allowed OSI to further enhance its capability to produce insensitive melt pour explosive products in a much larger capacity.

This paper details the process development and product qualification of IMX-101 at the new explosive manufacturing facility, as well as other special features and improved capabilities.

1. INTRODUCTION

BAE SYSTEMS Ordnance Systems has been manufacturing RDX and HMX explosives and their derivatives at Holston Army Ammunition Plant (HSAAP) for many years. And until recently, a new type of insensitive explosive ingredients such as DNAN, NTO and NQ were added to the product portfolio. And with extensive formulation efforts over a number of years, a new family of insensitive melt pour explosive featuring such ingredients had been successfully developed at HSAAP. These explosives had been developed and fielded in various end items in order to comply with the DOD 5000.2R, which requires munitions to withstand unplanned stimuli to improve the warfighter survivability in theater.

IMX-101 and IMX-104 are examples of insensitive melt pour explosive formulations developed by BAE Systems at Holston Army Ammunition Plant (HSAAP) as a replacement for TNT and Composition B representatively. In previous IM EM technical symposiums, the development efforts and IM performance of IMX-101 and IMX-104 had been report [1,2,3]. While the manufacturing processes for these insensitive melt pour explosives are relative similar in principle to the legacy explosives, they have much tighter tolerances in various processing parameters and they are slightly more complex in order to maintain consistent IM quality. The current melt pour manufacturing facility in Building L-4, where IMX-101 and IMX-104 were developed, is sufficiently adequate to produce good quality product with existing processing equipment. However, the success of these IM melt pour explosives leads to significant increase in customer interest and it is anticipated the demands for these explosives will increase beyond the current capacity.

BAE SYSTEMS had identified the need for a modernized, state-of-the-art melt pour explosive manufacturing facility in order to manufacture IM explosives more effectively and efficiently. This new facility will provide HSAAP with the capability and capacity to meet future IM explosive production requirements across multiple products. Under partnership with the Project Manager Combat Ammunition Systems (PM-CAS), the Munitions Engineering & Technology Center (METC) at ARDEC and financial support from Project Director Joint Services (PD-JS), a modernization project was executed, which involved demolition and retro-fitting of an existing building (Building M-4) at HSAAP.

Photos of the exterior structure of the old and new melt-pour facility at Building M-4 are shown in Figure 1A and B.

Figure 1A Legacy Melt Pour Facility at Bldg. M-4

Figure 1B Modernized Melt Pour Facility at Bldg. M-4

2. IMX-101 OVERVIEW

IMX-101 had been selected as the IM explosive formulation to replace TNT in 155mm M795 artillery projectile after it had demonstrated significant improvement in IM responses when compare to TNT. IMX-101 had been qualified as an main fill explosive by the US Army Energetic Material Qualification Board (EMQB) in February 2010 and had achieved type qualification with the 155mm M795 projectiles. It is currently being evaluated for other artillery projectiles such as the 105mm HE M1 and 155mm M1122. Table 1 shows the IM test results for IMX-101, loaded in 155mm M795 projectiles without packaging.

Table 1 IM Test Results of IMX-101

IM Test	Fast Heating	Slow Heating	Bullet Impact	Fragment Impact	Sympathetic Reaction	Shaped Charge Jet
PASSING CRITERIA	Type V	Type V	Type V	Type V	Type III	Type III
TNT (baseline)	FAIL Type III	FAIL Type III	FAIL Type IV	FAIL Type IV	FAIL	FAIL
IMX-101	Type V PASS	Type V PASS	FAIL Type IV*	Type V PASS**	PASS	PASS

* Passed original BI Test with one 50-cal bullet through supp. Charge, but failed (Type IV) with new test criteria of 3 50-cal bullets through supp. Charge (the lifting plug ejected > 50 feet)

** IMX-101 main charge targeted

It is apparent that IMX-101 had exhibited superior IM properties over TNT in most of the IM test scenarios.

IMX-101 is a melt-pour explosive formulation which comprises of 2,4-Dinitroanisole (DNAN), Nitrotriazonlone (NTO) and Nitroguanidine (NQ). These starting ingredients had been manufactured at Holston Army Ammunition Plant (HSAAP) for over 10 years under robust

manufacturing processes. IMX-101 is part of a family of DNAN based insensitive melt pour explosives currently manufactured at HSAAP. This next generation of insensitive melt pour explosive can be found in Table 2.

Table 2 A Family of IM Melt Pour Explosive manufactured at HSAAP

Product	Key Ingredients	Purpose	Qualification Status	Quantity (LB.)
IMX-101	DNAN + NTO + NQ	TNT replacement (for Artillery and other large caliber munitions)	Material qualified; Type qualified for 155mm M795, on-going for 155mm M1122 and 105mm projectiles	~ 2.2 M
IMX-104	DNAN + NTO + RDX	Comp B replacement (for mortar applications)	Material qualified; Type qualification on-going for 60mm & 81mm mortar, 120mm to follow	~ 782 k
PAX-48	DNAN + NTO + HMX	Comp B replacement (for mortar & tank ammunition)	Material qualified; Type qualification achieved for 120mm IM HE-T tracer round (NAMMO)	~ 180 k
PAX-21	DNAN + RDX + AP + MNA	Main fill for the 60mm M768 Mortar Rounds	Currently in-use in theater	~ 850 k
PAX-41	DNAN + RDX + MNA	Main fill for the Spider Grenade	Currently in-use in theater	~ 70 k

3. IM Melt Pour Explosive Manufacturing Facility Modernization Program

3.1 Background

The typical manufacturing process and the process optimization effort of the newly developed IMX products had been previously reported [4]. One of the key elements of this modernization program was to incorporate several new design concepts in this project as well as adapting state-of-the-art technologies in the final design of the equipment and building layout. The ultimate goal of this modernization was to construct a new manufacturing facility capable of producing IM explosives more efficiently, with improved product consistencies. The streamlined manufacturing process will lead to increase of capacity, which is essential to BAE Systems' ability to fulfill the increasing demands of IM explosive.

Building M-4 was selected as the new IM melt pour explosive manufacturing facility. It is located adjacent to the other two melt-pour explosive buildings, both are currently operating to manufacture products such as Composition B, Octol and IMX-101/104. Prior to the demolition, Building M-4 was a legacy melt-pour explosive facility, producing TNT based melt-pour explosive for many years but it had been in layaway status for a long time (Figure 2).

Figure 2 Building M-4 prior to modernization program

The modernization project was funded by the US ARMY Project Director Joint Services (PD-JS). The integrated project team to execute this program includes Project Manager Combat Ammunition Systems (PM-CAS), ARDEC Munitions Engineering & Technology Center (METC) and BAE Systems.

3.2 Program Timeline

Demolition and construction began in March and May 2011 respectively and the construction was completed in December 2012. In March 2013, an inert prove out trial was executed in order to evaluate the effectiveness of the new equipment and to provide training opportunities for the plant operators at HSAAP. A “live” prove out using IMX-101 was executed in September 2013, when explosive material were processed in the new equipment for the first time. After some minor design and processing parameters changed, IMX-101 was manufactured for the First Article Testing (FAT) at the modernized facility in April 2014. All the test requirements for the IMX-101 FAT were passed and subsequently the Modernized IM Melt Pour Manufacturing Facility was approved for IMX-101 manufacturing in December 2014.

To date, over 300,000 lbs. of IMX-101 had been manufacturing at the new facility. IMX-104 manufacturing will follow suit pending approval from the competent authority from the US ARMY. The FAT testing of IMX-104 is currently planned for Quarter 2 of 2015.

3.3 Design

The Modernized IM Melt Pour Manufacturing Facility features several new designs that will improve the overall process efficiencies and product qualities, resulting in a streamlined process which will ultimately increase the product throughput. Examples of the new designs include:

a.) New melt and incorporation kettle configuration (Figure 3)

As the DNAN melting process had been identified as the rate determining step for the overall operation, a new melt kettle is added specifically for DNAN melting purposes, reducing the overall cycle time.

Figure 3 Melt and Incorporation Kettle

b.) Modified kettle discharge (Figure 4)

A new pneumatic slide gate valve was designed to provide better flow control of molten product onto the casting belt, resulting in improved consistency. The value was computer controlled, with steam jacketed to keep product molten during discharge. Also, the new design utilizes the full width of the casting belt, shortening the casting time significantly.

Figure 4 Modified Kettle Discharge Valve

c.) State-of-the-Art Casting Belt System (Figure 5)

Several new features of the casting belt include a variable-speed casting belt, which will allow adequate control of the cooling rate depending on the cooling profile/characteristics of the product. A water chiller system provides the capability to control cooling water temperature, resulting in consistency processing conditions. The newly designed casting belt is now fully enclosed, which eliminates water exposure to the product from splashing.

Figure 5 Modified Casting Belt

d.) New Flake Breaker (Figure 6)

The new flake breaker is capable of sustaining high rate of flake breaking and produces smaller flakes in comparison to the legacy facility. The smaller flake size will benefit LAP operation as the time to re-melt will be reduced.

Figure 6 Modified Flake Breaker

e.) Other Major Improvements

Other major building improvements include upgrade in the ventilation system to provide pleasant work environment for operators (reduced operator exposure and consistent room temperature); plastic sheeting covering walls and ceiling to prevent contamination; LED lighting to provide energy savings; and a new loading dock, providing easier access to transport ingredients and products.

3.4 Capabilities and Capacities

The modernized melt pour manufacturing facility is designed to produce up to 10,000 lbs. of IM melt pour explosive per day. It is also capable of producing even larger quantity of legacy explosive products such as Comp B, as the cycle time is significantly less.

The reduced process cycle time is achieved by several factors:

- New kettle configuration to separate the melting and mixing operations
- New kettle discharge valve allows better utilization of casting belt space during casting
- Variable-speed casting belt reduces general casting time

New instrument had been installed to collect processing data throughout the new facility. These instruments can provide processing data logging capability, which will be utilized for statistical data analysis in order to establish Statistical Process Control (SPC) in various areas.

3.5 Process Flow Diagram

In order to highlight the major changes from the legacy facility to the modernized facility, two process flow diagrams (PFD) can be compared (Figure 7 and 8) directly.

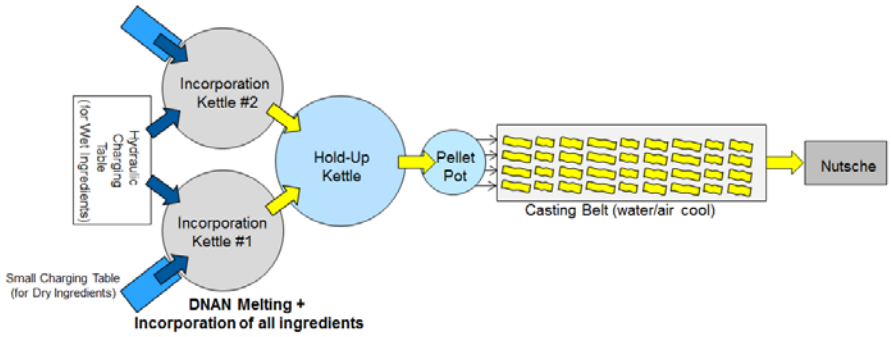

Figure 7 Process Flow Diagram of the Legacy IMX Manufacturing Process

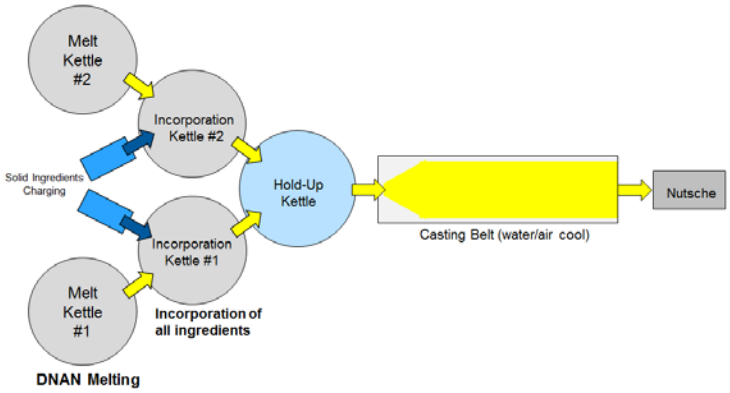

Figure 8 Process Flow Diagram of the Modernized IMX Manufacturing Process

The main difference between the two processes is the new melt kettle arrangement shown in Figure 8, where the DNAN melting and IMX incorporation are separated by two dedicated kettles. Once DNAN melting is completed and the molten DNAN is transferred to the incorporation kettle, the DNAN melt kettle is available to start another batch of IMX immediately to speed up the overall process. Another new feature is the utilization of the additional space on the casting belt. By casting the material directly onto the belt, more molten material can be cast at a much shorter period. Combining this with the adjustable-speed feature on the casting belt, the casting time can be reduced significantly when compare to the legacy equipment.

The finalized PFD on the modernized melt-pour explosive manufacturing facility is shown in Figure 9.

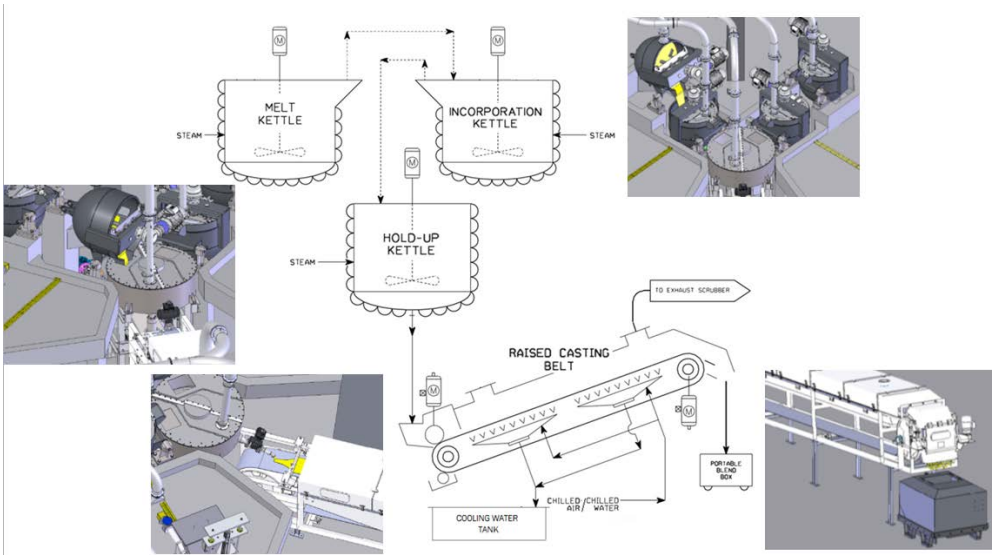

Figure 9 Finalized PFD of the Modernized Melt-Pour Explosive Manufacturing Facility

4. CONCLUDING REMARKS

Over the past few years, the demands of IMX-101 and other IM melt pour products had increased significantly. In order to meet this increasing demands as well as improving the process efficiency, product quality and consistency, a modernization process to construct a State-of-the-Art IM melt pour explosive manufacturing facility was executed at HSAAP.

BAE Systems, under the support from PD-JS and partnership with PM-CAS and ARDEC METC, had successfully commissioned the new facility. It is now in full operation and over 300,000 pounds of IMX-101 had been manufactured since Dec 2014. The new facility is capable of manufacturing over 3 million pounds of IMX explosive per year. This is a significant achievement in terms of providing our warfighters with safer munition products both at home and in theater worldwide.

5. ACKNOWLEDGEMENT

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