[1]Scheme to Reliably Initiate Insensitive Fill in the 500 Pound Warhead

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Background

The US Department of Defense, in its continuing search for an improved insensitive explosive fill in general purpose bombs, is examining alternative main fill explosives. The current candidate explosives for the 500 pound MK-82/BLU-111 warhead are a Naval Surface Warfare Center **P**olymer **B**onded e**X**plosive **I**ndian **H**ead division developed PBXIH-140, **A**ir **F**orce e**X**plosive formulation AFX-770 and **AL**uminized , **I**nsensitive **M**unitions e**X**plosive ALIMX-101. The initial candidate for testing is the aluminized version of the dinitroanisole (DNAN) based explosive IMX-101, developed by BAE Systems and the US Army. As a large critical diameter, 5.0 in. (12.7 cm.), low sensitivity explosive organic compound ALIMX-101 is more difficult to initiate with traditional inventory bomb fuzes. The primary method to ensure the explosive transfer from fuze to main fill is by the incorporation of an auxiliary booster around the fuze liner, embedded in the explosive. The selection of this booster material demands chemical compatibility with the main explosive along with a booster shape and output capable of sustaining the detonation of the new insensitive explosive. Since this general purpose warhead can be fuzed in the nose or tail, an auxiliary booster is required around both fuzewells.

Reliable initiation of an insensitive explosive is paramount to being able to weaponize it. The follow-on investigation will be to demonstrate the Insensitive Munitions (IM) characteristics against the Standardization Agreement (STANAG) IM test series. Finally an evaluation of weapon lethality will be required to justify the transition to an improved

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IM explosive. This paper will examine the process of selecting candidate auxiliary booster materials and the expected results of testing those candidates.

The US Army has developed and deployed several DNAN based explosives in smaller weapons including IMX-101 in the 155mm (6.1 in.) artillery round. This investigation is an attempt to scale up the application of a DNAN compound for IM improvements, especially in the sympathetic reaction test in general purpose aircraft delivered warheads.

Warhead Design

The concept is to maintain the existing warhead enclosure and fuzewells of the standard Mk-82 along with weight and balance criteria so that integration with existing guidance kits will remain a drop-in replacement. The current improved IM filled version of this warhead for the US Air Force and US Navy is designated the BLU-111.

Since the internal geometry of the case differs between the nose and tail of the warhead, as shown in figure 1, the booster design is driven by several factors. In the nose, the proximity of the warhead case walls tends to reflect and focus a blast wave because of the conical interior walls. The existence of the internal conduit connection to the forward fuzewell complicates the concept of installing a pre-formed forward fuzewell booster. Based largely on this consideration, the decision was for the entire nose cavity around the fuzewell to be cast with a more sensitive booster material than the main fill, cast in place before adding the main explosive fill. This resulted in a decision to use a melt-pour explosive formulation in the nose.

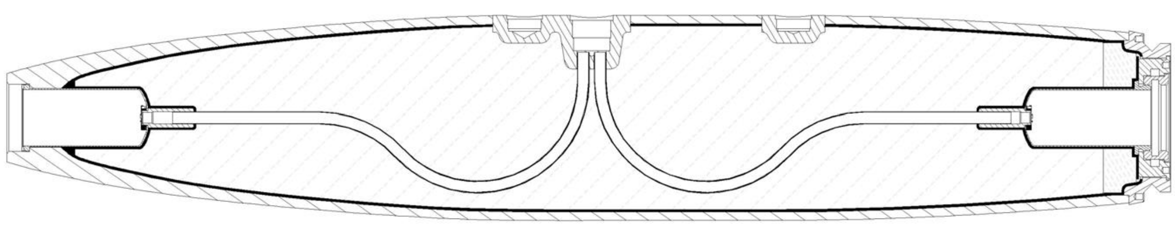

Figure 1. Cross-section of the 500-pound Bomb

The aft fuzewell zone is shaped more like a tube and the challenge is to direct the energy from a side light fuze down the length of the tubular warhead. Several aft booster designs were considered to make the fuze detonation “turn-the-corner” and propagate down the length of the main explosive charge.

Auxiliary Booster Design

For the nose auxiliary booster, the most significant decision was the depth of the booster material. Approximately 2 inches beyond the fuzewell was selected as an appropriate fill height, as seen in figure 2, to allow visual confirmation at the end of the internal conduit connection.

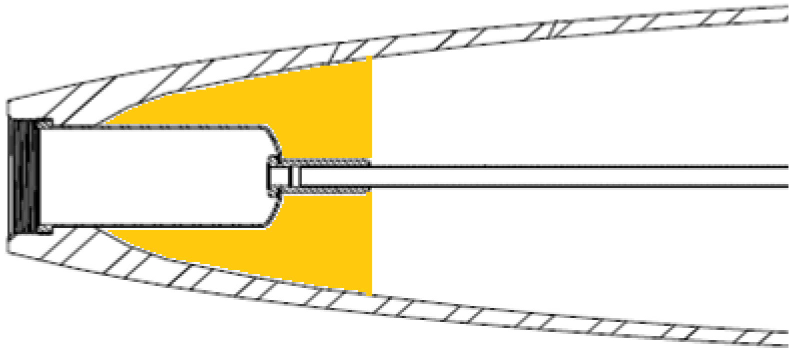

Figure 2. Forward Fuze Booster Cast Around Fuzewell

For the aft auxiliary booster a number of basic shapes were analyzed through modeling, ranging from a conical design with a 25° interior angle, a second conical design with a 15° interior angle, and a cylindrical booster with a rounded bottom. For the sake of simplicity and producability, two designs emerged for detonation testing, the 15° interior angle conical design and the cylindrical booster with a rounded bottom, shown in figure 3.

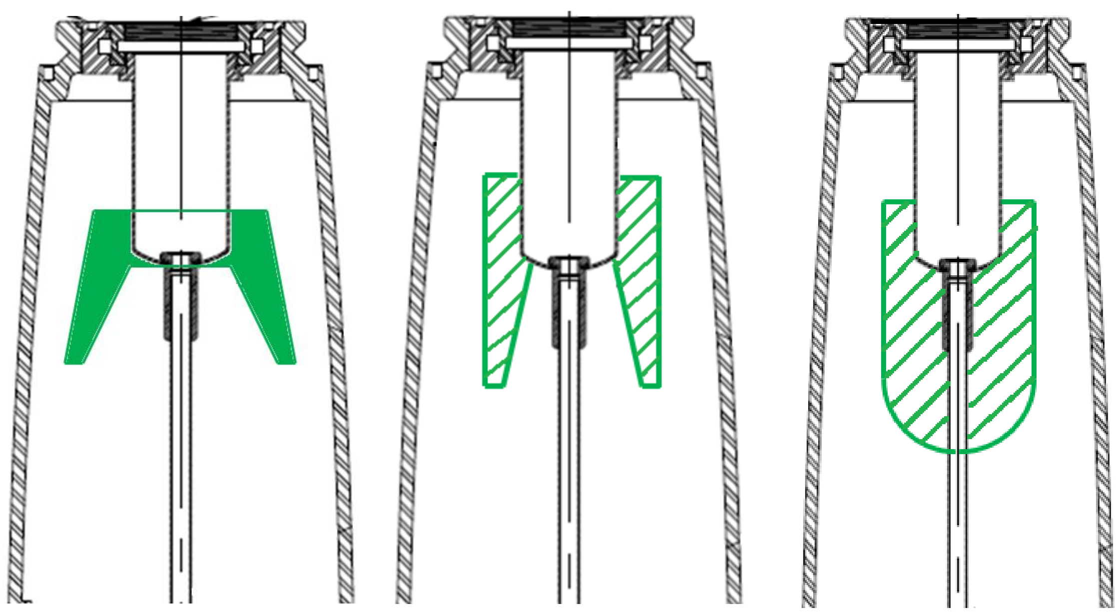

Figure 3. Aft Auxiliary Fuze Booster Attached to Fuzewell

Modeling by Gunger Engineering, looking at 30 µsec after initiation, indicates either aft booster shape should grow to a full warhead diameter detonation as shown in figure 4.

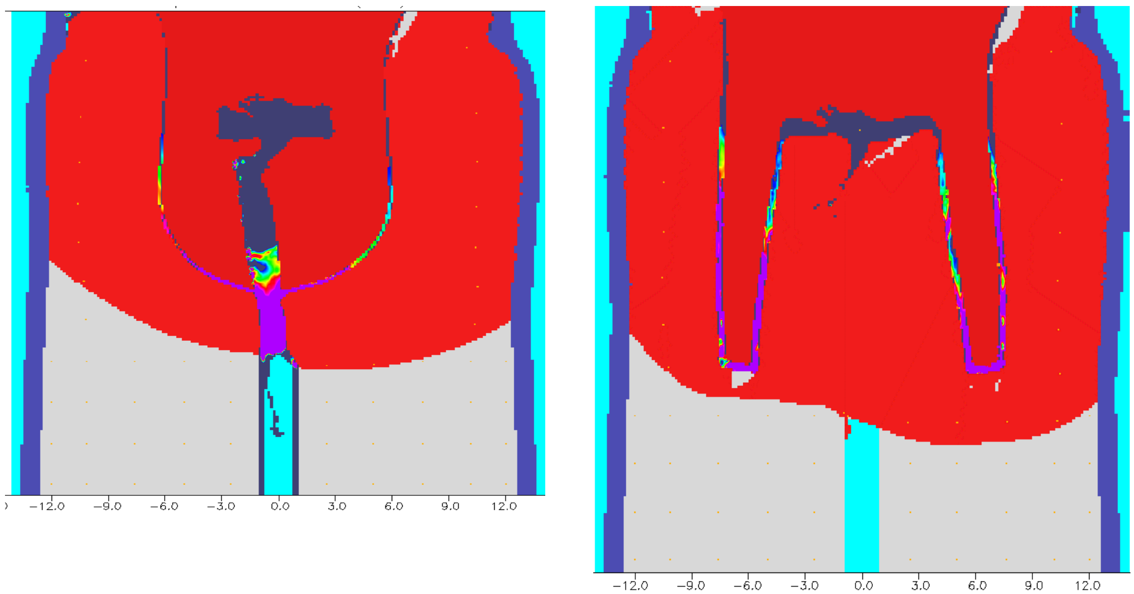

Figure 4. Aft Main Fill Initiation

Auxiliary Booster Material

The next decision was what booster material to use. Since the ALIMX-101 is a melt-pour material, it seemed logical to use a similar material for the boosters. Since the ALIMX-101 is molten when cast into the warhead 190° – 200°F (87.8° – 93.3℃), the melt temperature of the booster material needed to be no lower than the main fill material to be added to prevent compromise of the booster shape. The auxiliary booster could be either a pressed, melt-pour or a cast-cure material. These assumptions would limit the available qualified explosives used as boosters. Only boosters that were qualified for safety and performance and had a completed fill specification were analyzed.

Table 1. Original Auxiliary Booster Candidates

IMX-104	PBXN-7	PBXW-14
PAX-21	PBXN-11	AFX-795
PAX-28	PAX-2A	AFX-196
PAX-48	PAX-41	AFX-256
PBXN-110	PAX-46	
PBXN-5	PAX-195	
PBXN-9	OSX-9	

Options for aft booster production included casting the main fill around a former, then returning to remove the former and fill the cavity with booster material. The alternative is to pre-cast the boosters and install them on the fuzewell prior to filling the warheads with ALIMX-101. The team decided that the pre-cast booster concept would produce more consistent configuration for testing and future production even though it limits the space to flow molten ALIMX-101 between the booster and the warhead case wall.

The common legacy fuze used to initiate general purpose bombs in the US Air Force is the FMU-139B/B with a PBXN-7 fuze booster. Therefore the down selection of compatible auxiliary booster materials with apparent sufficient output included PAX-48, PAX(AFX)-196, and PBXN-110. PAX-21 and PAX-48 are both DNAN based formulations. During early fuze to booster testing, PAX-48 was found unreliable for sustaining a detonation from the legacy fuzes used by the Air Force at low temperature. Thus PAX-48 was removed as a candidate, replaced by PAX-21 and PBXC-139. The nose auxiliary booster materials selected are melt-pour PAX-21 and PAX-196. For the aft auxiliary boosters, PAX-196 and PBXC-139 are being cast as rounded bottom cylindrical boosters and PBXN-110 is being used in the conical shape. Table 2 shows the boosters selected for half bomb initiation evaluation and table 3 explains the IUPAC identifier and molecular formula for reference.

Table 2. Auxiliary Booster Materials

Auxiliary Booster Material	Cast Method	Install Location	Major Ingredients
PAX-48	Melt pour	Tail	NTO, DNAN & HMX
PAX(AFX)-196	Melt Pour	Nose and Tail	RDX, wax & DOA
PBXN-110	Cast Cure	Tail	HMX & HTPB binder
PBXC-139	Cast Cure	Tail	RDX & LMA
PAX-21	Melt Pour	Nose	DNAN, AP & RDX
PAX **P**icatinny **A**rsenal e**X**plosive **PBX** **P**olymer **B**onded e**X**plosive N=Navy, C=China Lake **AFX** **A**ir **F**orce e**X**plosive			

Table 3. Major Ingredient Reference

Ingredient	**International Chemical Identifier** (IUPAC name)	Name Reference	Molecular Formula
DNAN	1-Methoxy-2,4-dinitrobenzene (aka: 2,4-dinitroanisole)	TNT replacement	$C_7H_6N_2O_5$
HMX	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	**H**igh-**M**olecular-weight rd**X**	$C_4H_8N_8O_8$
LMA	dodecyl 2-methylprop-2-enoate (aka: Dodecyl methacrylate)	**L**auryl **M**eth**A**crylate	$C_{16}H_{30}O_2$
NTO	3-nitro-1,2,4-triazol-5-one (aka: hydrazinium)	low vulnerable explosive	$C_2H_2N_4O_3$
RDX	1,3,5-Trinitroperhydro-1,3,5-triazine (aka: Cyclotrimethylenetrinitramine)	**R**esearch **D**epartment Formula **X**	$C_3H_6N_6O_6$
TNT	2-Methyl-1,3,5-trinitrobenzene (aka: 2,4,6-Trinitrotoluene)	Reference	$C_7H_5N_3O_6$

Planned Testing Activities

A series of instrumented half bomb tests are planned to quantify the speed and shape of the blast front from fuze initiation, through the auxiliary booster and into the main explosive fill as shown in figure 4. Rows of piezoelectric pins will measure the detonation along opposite walls and down the center of the half bombs. These initiation tests at -65°F (-53.9°C) along with a sympathetic reaction test of live warheads in a standard shipping/storage pallet at ambient temperature, shown in figure 5, will determine the viability of ALIMX-101 as an IM candidate explosive to move into full qualification.

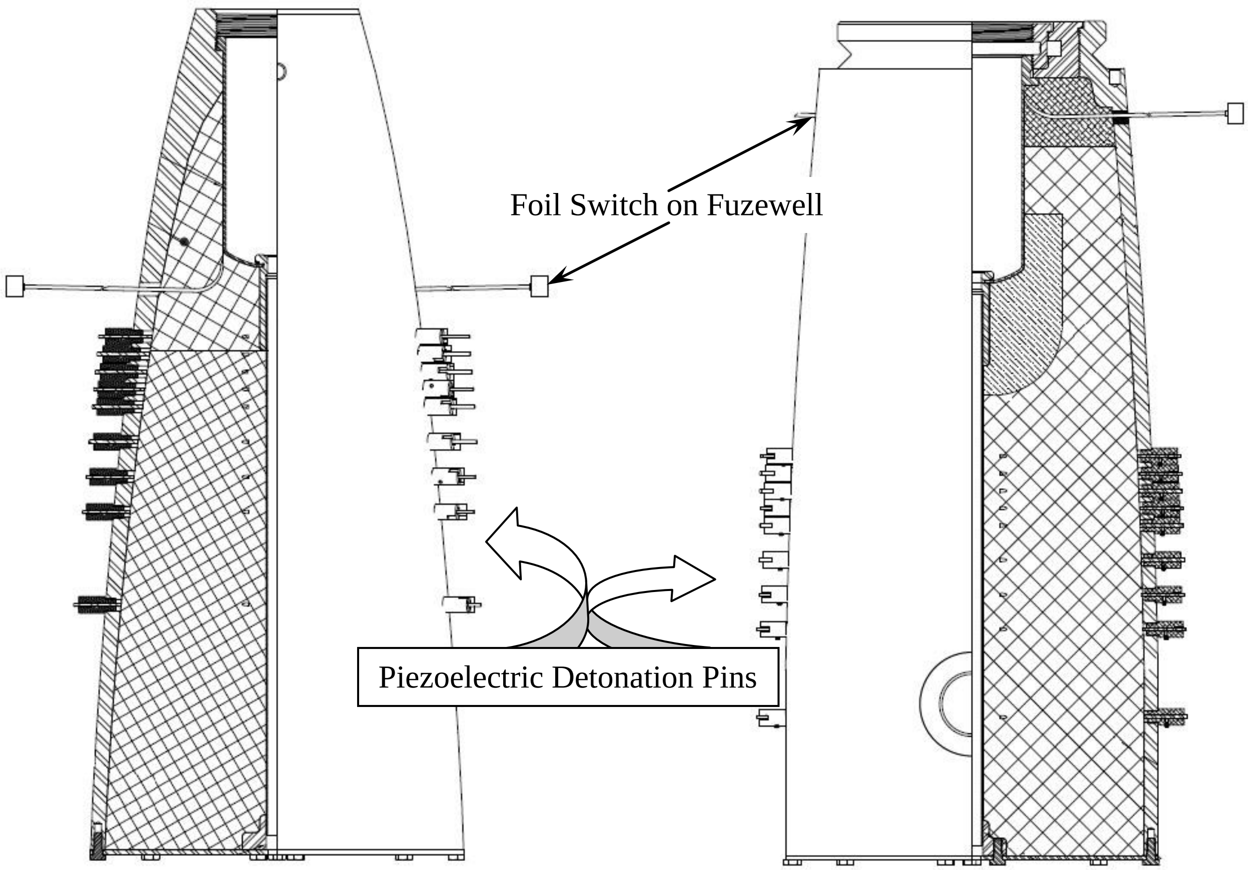

Figure 5. Half Bombs with Instrumentation

Some of the challenges during the sympathetic reaction test include very high speed camera coverage at both ends of the pallet to determine what happens as the detonation progresses. Witness plates must be sufficient in number and placement to indicate how the acceptors react. The difference in blast pressure between a single warhead and additional explosive reaction could be the key to determine overall reaction of the pallet stack. Recovery of sufficient fragments to determine what happened to the acceptors is always a challenge especially on ranges littered with previous fragments. Identifying which warhead a fragment is from is also a challenge.

Figure 6. Sympathetic Reaction Test in Pallet

Conclusions

Appropriate auxiliary booster materials have been analyzed and evaluated. Production methods have been analyzed. Testing is scheduled to determine if available auxiliary boosters will run-up the detonation of a large critical diameter explosive for IM improvements to general purpose warheads. Based upon the results of half bomb initiation tests and Sympathetic Reaction testing in a transportation/storage pallet a decision will be made to qualify ALIMX-101 as the next generation IM fill for the MK-82, 500 pound general purpose warhead. If the weaponization of this explosive fails to meet performance or safety criteria, then one of the other candidate explosives will be similarly evaluated.

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