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Insensitive Munitions (IM) Enhancement of the 120mm M934A1 High Explosive (HE) Mortar Cartridge

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ABSTRACT

The United States Department of Defense has mandated that munitions be designed to withstand unplanned external stimuli and improve survivability throughout its life cycle. A product improvement effort has been undertaken by the US Army Product Manager for Mortar Systems to enhance the IM characteristics of the 120mm M934A1 HE Mortar Cartridge. A best-value, systems engineering approach was employed to evaluate competing potential design modifications to the HE Body Loading Assembly (shell body and explosive fill) and cartridge packaging. Under this strategy, design and manufacturing trade-offs were made to maximize the cost-effectiveness of the IM-enhancements when compared to the potential threat hazards to mortar ammunition. New explosive formulations and cartridge design features were integrated into the overall system to achieve IM objectives. Substantial IM-enhancement has been achieved. In addition, performance (lethality) requirements have been met. Finally, Production Qualification Testing (PQT) has been successfully completed. A summary of the improvement in IM response versus the baseline design against shock and thermal threats (in accordance with MIL-STD-2105C testing) will be highlighted. The US Army will soon field mortar ammunition that will be less reactive to unplanned stimuli in its logistical and tactical environments. Decreased vulnerability of the ammunition will result in improved mortar survivability and mortar crew confidence.

BACKGROUND

In response to the United States Department of Defense Directive 5000.2-R that new munitions be designed to withstand unplanned external stimuli, the Office of the Product Manager for Combat Ammunition Systems has seized the opportunity to enhance the IM effectiveness of the 120-mm M93A1 High Explosive (HE) Mortar (Figure 1). The policy of the Under Secretary of Defense for Acquisition and Technology is to seek every feasible window of opportunity to insert IM technology into weapon systems in production. By exploiting available technologies, the Materiel Change program on the 120-mm M934A1 HE mortar is rapidly progressing and will result in a new IM-enhanced M934A2 HE cartridge.

Figure 1 – 120mm M934A1 HE Mortar Cartridge

IM test procedures and assessment levels are defined in MIL-STD-2105B/C[1] (Table 1). IM testing performed in accordance with MIL-STD-2105B established baseline reaction levels for Bullet Impact (BI), Fragment Impact (FI), Slow Cook-Off (SCO), and Fast Cook-Off (FCO) for the Composition B loaded 120-mm M934A1 HE mortar. It should be noted that both the Sympathetic Detonation and Shaped Charge Jet tests were assessed to fail (Type I reaction level); therefore, baseline testing was not conducted.

Table 1 – MIL-STD-2105B/C Reaction Definitions

Reaction Type	Reaction Definition	Reaction Description
I	Detonation	A supersonic decomposition reaction propagates through the energetic material to produce an intense shock in the surrounding medium and very rapid plastic deformation of metal cases, followed by extensive fragmentation. All energetic material is consumed.
II	Partial Detonation	Some, but not all of the energetic material, reacts as in a detonation. An intense shock is formed and some of the case is broken into small fragments.
III	Explosion	Ignition and rapid burning of the confined energetic material builds up high local pressures leading to violent pressure rupturing of the confining metal case. Unreacted and/or burning energetic material is scattered about.
IV	Deflagration	Ignition and burning of the confined energetic material leads to non-violent pressure release as a result of a low strength case or venting through case closures. The case might rupture but does not fragment and unburned or burning energetic material may be scattered about.
V	Burning	The energetic material ignites and burns, non-propulsively. The case may rupture non-violently, allowing mild release of combustion gases. Debris is not expected to cause fatal wounds to personnel or be a hazardous fragment beyond 15 meters.

Test results concluded that the Composition B high explosive fill and current packaging configuration were the major contributors to test failures, whereas the propulsion system and fuze were not major contributors for failing to meet IM test requirements.

DISCUSSION

A Threat Hazard Assessment[2] on the life cycle of the M934A1 HE mortar cartridge was conducted. The THA identified and characterized the most credible threats from enemy, accidental and terrorist events, and assessed the HE mortar cartridge's response to these threats. The most probable threats were identified to be Fast Cook-Off (FCO), Bullet Impact (BI), Fragment Impact (FI), and the Sympathetic Detonation (SD). Slow Cook-Off (SCO), Shaped Charge Jet (SCJ) and Spall Impact (SI) are additional threats.

A systems solution was sought to improve IM responses to shock and thermal stimuli. The overall goal of this program was to achieve cost effective IM-enhancement using known IM technologies for warhead and packaging designs, and production-ready high explosives. Competitive best value contracts were awarded to evaluate two independent systems designs for IM-enhancement of the M934A1 HE mortar.

Traditional IM-enhancement approaches focused on mitigating thermal threats by using controlled venting, insulation materials, and tailored energetic formulations. To mitigate shock and impact threats, barrier materials and less shock-sensitive explosive formulations were used[3,4].

High Explosive: The design approach for the M934A1E1 IM-Enhanced cartridge was to identify a replacement explosive with energy comparable to Composition B but with reduced shock sensitivity. The two best candidate high explosives were down-selected and subjected to limited safety, performance and IM testing. Both candidates are cast cure plastic bonded explosives (PBX). Key explosive properties are shown in Table 2. HBU-88B (Figure 2) was ultimately selected for use in the 120mm M934A1E1 HE mortar

Table 2 – Explosive Properties

Property	Composition B	AFX-231	HBU-88B
Density (g/cc)	1.72	1.72	1.62
Shock Sensitivity (NOL cards)	210	122	118
Gurney Energy (km/s)	2.68	2.72	2.65
Detonation Velocity (km/s)	7.97	7.85	8.18
Detonation Pressure (GPa)	29.5	26.0	27.1

Figure 2 – Cast-Cured HBU-88B High Explosive

Packaging: Packaging design modifications were required to mitigate shock and thermal stimuli. Several changes to the existing two-round metal over-pack and fiber unit pack were considered. Venting of the metal over-pack provided pressure relief during cook-off scenarios; however, hazardous fragments were still thrown beyond 49 feet. The final packaging design is shown in Figure 3, and includes use of a PA-174 Monopaq™ (unit pack) with the addition of customized barrier materials at the palletized load level to successfully mitigate sympathetic detonation and reduce the number of hazardous fragments thrown beyond 49 feet.

Figure 3 – Final Packaging Configuration

PA-174 Monopaq™ Container

Palletized Load Configuration

Warhead: Severity of energetic reaction is known to be a function of explosive confinement in thick walled projectiles. Venting is critical for limiting the warhead reaction to burning instead of transitioning to either an explosion or detonation. Accordingly, modifications to the projectile body were required to provide venting of combustion gases generated under cook-off reactions or impact stimuli.

IM TEST RESULTS

IM testing performed in accordance with MIL-STD-2105B established baseline reaction levels for BI, FI, SCO, and FCO for the Composition B loaded 120-mm M934A1 HE mortar cartridge (Table 3). Final IM testing (SCO, FCO, SD, BI, FI, and SCJ) was conducted on the IM-enhanced mortar cartridge using high explosive, packaging and warhead modifications described above. Testing was conducted in accordance with MIL-SD-2105C and respective STANGAGS. Test results are shown in Table 3. Substantial IM improvements have been achieved.

Table 3. Comparison of M934A1 IM Test Results

Test	M934A1 Baseline	M934A1E1 IM-Enhanced Design **
FCO	II	IV
SCO	I	IV
BI	I	IV
FI	I	IV
SD	I *	IV
SCJ	I *	IV

* Assessed as Type I based on results of Final Hazards Classification tests
** Preliminary Army IM Board scored results

CONCLUSION

A systems approach was used to achieve IM enhancement of the 120-mm M934A1 HE Mortar Cartridge. Significant progress has been accomplished in the effort to attain an IM-compliant mortar system by incorporating reduced sensitivity explosive fills, shock-mitigating packaging materials, and a vented shell body. The US Army will soon field mortar ammunition that will be less reactive to unplanned stimuli in its logistical and tactical environments. Decreased vulnerability of the ammunition will result in improved mortar survivability and mortar crew confidence.

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