155mm HE Projectile Qualification Program

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The United States Department of Defense has mandated that munitions be designed to withstand unplanned stimuli and improve survivability throughout its life cycle. The U.S. Army and U.S. Marine Corps field artillery units are equipped with the M109A6 Self Propelled Howitzer, M198, and/or M777A2 Joint Lightweight Towed Howitzers. The M795 High Explosive (HE) projectile provides the User with highly accurate and effective ammunition for attacking enemy forces from a distance.

A product improvement effort has been undertaken by the US Army Project Manager for Combat Ammunition Systems to enhance the IM characteristics of the 155mm HE projectile. A best-value, systems engineering approach has been employed to evaluate competing potential design modifications to the HE Body Loading Assembly (shell body and explosive fill) and packaging. Under this strategy, design and manufacturing trade-offs have been made to maximize the cost-effectiveness of the IM-enhancements when compared to the potential threat hazards to the ammunition. New explosive formulations and projectile design features are integrated into the overall system to achieve IM objectives.

A systems solution has been sought to improve IM responses to shock and thermal stimuli. The overall goal of this program is to achieve cost effective IM-enhancement using known IM technologies for warhead and packaging designs, and production-ready high explosives. IM-enhancement focused on identifying and implementing less shock-sensitive explosive formulations to mitigate impact and thermal threats. Less sensitive explosives, projectile venting techniques and packaging techniques have been identified for IM-enhancement of the M795 HE projectile.

High Explosive: The replacement IM explosive required energy comparable to TNT but with reduced shock sensitivity. An extensive search for an alternative less sensitive melt-pour explosive has been conducted leading to the selection of IMX101 as the new main charge explosive. The results leading to the downselect of IMX-101 to replace TNT from the Common Low-cost Insensitive Munitions Explosive program are presented in another paper at this conference. Since the IMX101 is shock insensitive and has a fairly large critical diameter, a new more powerful supplementary charge is required to initiate the M795 IM. PBXN-9 explosive has been tested and chosen to be the new supplementary charge explosive. Reliability of the test results with the new initiation are presented in a separate paper as part of this conference.

Warhead Venting: Severity of energetic reaction is known to be a function of explosive confinement in thick walled projectiles. Venting is critical to limit the warhead reaction to burning instead of transitioning to either an explosion or detonation. Accordingly, projectile modifications are incorporated to provide venting of combustion gases generated under cook-off conditions or impact stimuli. Since the M795 projectile utilizes a lifting plug to seal the shell body and conduct logistical operations, this plug was modified to permit projectile venting.

Several different lifting plug designs were developed and tested to evaluate performance during FCO and SCO reactions. Some lifting plug designs incorporated an

ionomer material that would soften at temperatures below the explosive reaction temperature to reduce confinement and prevent transition from deflagration to detonation. A melt-able fuze plug (MFP) demonstrated the ability to pass FCO and SCO. A lifting feature for the projectile will be incorporated into the MFP. The top pallet cover will be redesigned to add lunettes to lift the pallet.

The aluminum supplementary charge liner in the M795 can prevent venting of the melting explosive, thus causing failure in thermal IM tests (FCO and SCO). A new ionomer liner, which softens at high temperature, has been tested, evaluated, and implemented into the M795 IM projectile.

Below are pictures of the MFP, palletized projectiles and a cutaway of the projectile:

Qualification of the IM projectile

The U.S. Army Evaluation Center (AEC) and the Developmental Test Command (DTC) were consulted to develop a test matrix to qualify the M795 IM projectile. The basic premise of the change: M795 IM 155MM High Explosive (HE) Projectile is designed to incorporate features to limit the effects of unplanned stimuli. The M795 IM will perform the same function of the M795 with the same level of lethality, ballistic performance, safety and range as its predecessor. Since, the qualification is primarily aimed at improving the safety of the ammunition, DTC would provide a Safety Assessment at the conclusion of the effort.

Table 1 identifies the differences between the M795 and M795 IM HE 155mm projectile. Table 2 identifies M795 IM projectile characteristics.

Table 1. Design Differences Between M795 and M795 IM HE

Component	**M795**	**M795 IM**
Shell Body	HF-1 Steel	HF-1 Steel (same)
Lifting Plug	Cast steel	Plastic
Packaging	Standard pallet top	Modified pallet top
Palletized Unit Load	4x2	4x2 (same)
Warhead Fill	TNT w/ TNT booster	IMX-101 w/ PBXN-9 booster
Liner	Aluminium	Plastic

Table 2. M795 IM Projectile Characteristics (same as M795)

Weight (pounds) (nominal as fired)	103
Length (inches)	29.46
Maximum Range (meters)	22,500

(1) Key features and subsystems

(a) Hardware components of M795 IM 155mm Projectile
- Meltable Fuze Plug
- Projectile body w/ explosive, obturator band, and plastic liner
- Rotating Band Cover
- Supplementary Charge
- Spacer

Each test was designed to address one or more of the issues necessary to evaluate the system's effectiveness and suitability (Table 3). Test results provided safety, performance, and reliability data for the M795 IM Projectile. Where possible, the tests were planned according to statistical designs to minimize test quantities. In some

cases, the evaluation was dependent on comparisons with the M795 HE Projectile.

Effectiveness during the Production Qualification Testing (PQT) was addressed by evaluating the system performance in terms of precision, range capability, temperature extremes, and a ballistic match test. Other areas in effectiveness addressed included evaluating the system performance in terms of fragmentation characteristics and lethality of the IM explosive-loaded projectile. Assessment of suitability was addressed primarily by the ability of the M795 IM projectile to meet the reliability requirement. Additional issues addressed under suitability included safety and logistics.

Table 3. Measure of Effectiveness and Suitability (MOE&S)

	PARAMETERS	REQUIREMENTS
1	EFFECTIVENESS:	Projectile Dimensional and Weight Match to the M795. Lethality must be equal to or greater than that of the lethality of the M795. Ammunition must have a maximum range of 22,500 meters. Precision for long range: the range probable error shall be within 0.30 percent of the mean range. For short ranges the probable error shall not exceed the greater of: 1 mil, or 15 meters of the M483A1. For direct fire, the vertical and horizontal probable error with the maximum propelling charge shall not exceed 0.3 mils at 1800 meters range. Capable of operation in cold, hot and ambient environments System precision must be maintained when subjected to adverse environments
2	SUITABILITY:	Low safety risk for storage, transport, handling and use Reliability of the fuzed projectile shall be no less than the quantified value for reliability of the standard/fuze projectile combination. Must comply with Human Factors Engineering requirements Must be logistically supported in its operational environment Must comply with Insensitive Munitions requirements of MIL-STD 2105C, TB-700-2 as well as JSIMTP IM standards

(2) Interfaces

(a) The projectile was developed to provide long range and lethal capability. The M795 IM was designed in line with this original objective while also increasing the munitions survivability when exposed to a variety of unplanned stimuli.

(b) The M795 IM Projectile will be fired from the M109 series, and/or the M777, and/or the M198 howitzer platforms. The projectile will be compatible with all existing standard fuzes for 155mm artillery HE projectiles.

(3) Unique Characteristics

The projectile contains an IM explosive fill (IMX-101), a PBXN-9 supplementary charge housed in a plastic liner. A meltable fuze plug has been incorporated to aid in projectile venting.

Developmental Test and Evaluation Phase

a. Test and Evaluation Overview

The M795 IM HE Projectile IM program evaluated the M795 IM projectile as outlined in Table 4 and compared its lethality and overall effectiveness to that of the M795 projectile.

Table 4. Test Matrix

TESTS	M795 IM TEST RDS
SAFETY	
Velocity Pressure Check	30
12-meter Drop	10
Initial Safety Test	
Hot/Dry Cycle (7 days)	30
Cold Soak (7 days)	30
Sequential Environmental Test	
Hot/Dry Cycle (28 days)	60
Cold Soak (14 days)	60
Shock Attenuating Lifting Plug	40
Worn Tube	40
EOD	16
ADVERSE ENVIRONMENTS	
Solar Radiation	8
High Humidity & Temperature	16
Fungus	8
Long Term Storage - Uncontrolled	16
PERFORMANCE	
Firing Tables	45
Arena Fragmentation	3
INSENSITIVE MUNITION	
Fast Cook-off	9
Slow Cook-off	2
Sympathetic Detonation	16
Fragment Impact	2

TESTS	M795 IM TEST RDS
Shaped Charge Jet Impact	2
Bullet Impact	3

b. Test Results and Analysis. An IPT was formed to execute the M795 IM HE Projectile Qualification. The IPT, comprised of members representing various areas of expertise, were required to perform an overall independent evaluation. The IPT used data from all available and appropriate sources and integrate the data to evaluate the M795 IM. Quality Engineers conducted and monitored developmental testing in controlled environments by specially trained individuals to assess the adequacy of the system design, to determine compliance with system specifications and technical parameters and to determine how safe the system is for operation by user troops and civilians. The IPT integrated the results of all testing to provide an efficient and effective evaluation. The conclusion of the IPT was that the M795 IM projectile has met the requirements identified in Table 3 and the IM projectile meets the lethality and effectiveness requirements while improving the safety of the projectile. Based on successful execution of the test plan, Development Test Command issued an independent Safety Confirmation for the M795 IM projectile on 2 March 2010. The following IM scores were achieved for the M795 projectile:

IM Test:	FCO	SCO	BI	F1	SD	SCJI
M795 IM Scores*	V	V	IV	V	Pass	Pass

*Reaction from IMX-101

Program Status

The Technical Data Package for the M795 IM projectile was signed on 17 June 2010. The transition into production of the M795 IM projectile will begin CY11.

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From the Common Low-cost Insensitive Munitions Explosive Program under execution by Project Manager for Combat Ammunition Systems, IMX-101 was selected to replace TNT. For qualification of the new energetics and the main charge explosive in the ammunition, the 155mm M795 projectile was selected as a test vehicle. Developed in the early 1980s for providing support fire of blast effect, fragmentation and mining, the 155mm M795 projectile uses approximately 24 lbs of high explosive loaded in a high fragmenting steel body. The projectile can be fired from the lowest to the highest service charge.

The qualification program consisted of a battery of tests on the projectile per International Test Operating Procedure (ITOP) 4-2-504 (1) - Safety Testing of Field Artillery Ammunition, Insensitive Munitions test per MIL-STD-2105C and Arena Tests for Lethality. The safety tests consisted of subjecting the projectile to severe environmental conditions, logistical and tactical vibrations, drop tests followed by ballistic firings at top or overpressure charges to validate the design. The IM tests were combined with the Final Hazard Classification tests to validate the dramatic improvement that were demonstrated during the Phase 1 and 2 of the CLIMEx program. The overall hazard classification of the projectile was reduced from 1.1 based on the IM/FHC results.

This paper will present the test results and the U.S. Army's program to qualify the IM 155mm M795 HE projectile.

Bio for Authors

Charlie Patel and Philip Samuels are in the Energetics Components Branch in the Office of the Project Manager for Combat Ammunition Systems, where they direct most activities in the areas of IM explosives and their interface with current and developmental artillery and mortar systems. Ductri Nguyen and Anthony Di Stasio work in the Munitions Engineering & Technology Center , Research Development Evaluation Command-Armament Research & Development Engineering Center at Picatinny Arsenal, NJ where they develop technology solutions to provide the User with safe and effective munitions.