Common Low-cost Insensitive Munitions Explosive to Replace TNT and Comp B

J. Rutkowski, R. Cirincione, C. Patel
Office of the Project Manager for Combat Ammunition Systems
Picatinny Arsenal, NJ 07806-5000

Abstract

One of the tenets of the Project Manager for Combat Ammunition Systems (PM-CAS) Mission is to perform life-cycle management of tube-launched indirect fire munitions. Contained within this area are high-explosive (HE) projectiles and cartridges for artillery and mortar applications. There are a total of thirteen HE projectiles: four for 105mm artillery, three for 155mm artillery, two for 60mm mortar, two for 81mm mortar and two for 120mm mortar. All of these HE cartridges use either TNT or Comp-B fill.

In the summer of 2005, the PM decided to take a holistic review of pursuing IM. What was found that in pursuit of insensitive / less-sensitive HE fills, each projectile program investigated individual solutions tailored to their specific requirements depending upon the stage of the life-cycle and the schedule for anticipated production buys. This resulted in the selection of a different HE fills for each artillery and mortar projectile. These programs did not necessarily take into account cost or industrial base impacts, and their effect on the insensitivity was achieved to varying degrees with none having achieved full I.M. compliance. At the same time, a review of the Program Executive Office for Ammunition's (PEO-Ammo's) IM Thrust program and the Army's RDT&E (ARL and ARDEC) showed significant achievements and maturity of technology within the last several years.

Based on the above, an executive decision was made to pursue a Common Low-cost Insensitive Monitions Explosive (CLIMEX) to identify new explosive fills for artillery and mortar applications that are common fills, affordable and less sensitive. The CLIMEX Program Goals were as follows:

- **Primary Goal** -- Selection of one single common explosive fill for all artillery and mortar products
- **Secondary Goal** -- Selection of two explosive fills, one that is common for replacement of TNT and another that is common for replacement of Comp B

The CLIMEX Program strategy is to rapidly accelerate candidate explosive fill formulations / compositions that satisfy the selection criteria into test materiel using representative manufacturing facilities. Small-scale tests will be used to ascertain indications of its response, followed by full-scale tests and eventually arena tests to determine lethality.

The CLIMEX Program will take into consideration potential candidates from Government and Industry, as well as historical explosives that were abandoned due to the discoveries of newer, more powerful explosives or during the Cold War era when the emphasis was placed on ever-increasing lethality. The Program metrics are cost, insensitivity, and lethality.

This paper will present an overview (background, protocol and results) of the U.S. Army's program to qualify a low cost, common IM explosive to replace TNT and Comp B.

Background

In the summer of 2005 as several of the artillery and mortar Insensitive Munitions efforts were approaching successful milestones; it became evident that the numerous approaches to IM created Industrial Base issues. While the programs was successful in developing and qualifying less sensitive munitions, the solutions all used different formulations and required different facilities to produce and load the munitions. Investing in multiple facilities that would be capable of loading all mortar and artillery projectiles with a melt-pour, cast-cure or pressed explosive fill would cost hundreds of millions of dollars. In addition, the recurring cost of the explosives exceeded $10 (US) per pound. When compared to a M795 containing approximately 25 pounds of TNT, the item cost with an IM fill would increase by $200 (US) or more.

Based on the potential cost of the current solutions, the PM requested the Energetic Components Branch do an independent evaluation of the IM programs. While reviewing the artillery and mortar programs, the team attended reviews held for the Program Executive Officer's IM Thrust Program and the Army's Novel Energetics Program. What became obvious was that technology had significantly advanced and more affordable solutions were within reach.

During the out-briefing to the PM and his officers, it was decided that the PM office would pursue a program for a Common Low Cost Insensitive Munitions Explosive (CLIMEx). The primary goal of the program was commonality; the most favorable outcome would be one IM explosive to replace TNT and Comp B but finding a common replacement for TNT and another common replacement for Comp B is certainly an acceptable solution as well. The program was to capitalize on existing technology and to make a recommendation in a 6 to 12 month timeframe.

To meet the requested schedule, it was decided that we would focus on the TNT solution first (with the hopes of finding the common TNT and Comp B solution) and we would use the M795 projectile as the test vehicle since it was the best defined baseline. The follow-up testing for the Comp B replacement would use the 120mm HE mortar cartridge, however, at the beginning of the Comp B program, immediately after the initial screening of candidates, it was decided to utilize the 81mm HE mortar cartridge as the test vehicle because the Army purchased significantly more 81mm cartridges than 120mm cartridges.

Discussion

TNT Replacement

The 155mm M795 HE projectile was considered the worst case from previous insensitive munitions testing and had a well defined baseline with TNT. From past experiences, it was known that candidate explosives will fail the thermal tests without some type of venting, therefore, it was decided the test protocol will be a projectile with a vented lifting plug. Standard palletization was mandatory, that is, 8 projectiles to a pallet with no barriers between the projectiles.

The test protocols were established considering the cost of each test and the ease to set-up and perform the testing. The result was a three tier effort beginning with bullet impact, slow cookoff, and fragment impact. The candidate explosive had to be equivalent or better than the baseline TNT in every test and had to do better in at least one of the tests to proceed to the next tier testing. The second tier test consisted of a 2x2 sympathetic detonation with the diagonal projectiles being the donor and acceptor. Tier 3 testing was to be performed on the downselected candidate(s) and consisted of shaped charge jet and fast cookoff to complete the IM series of testing. All testing, whenever possible, was done in duplicate.

Using Government, Industry and International sources, 23 explosive candidate formulations were identified. These formulations were categorized as inert binder or energetic binder and the further categorized as melt-pour, cast-cure, or pressed explosives. The potential candidates to replace TNT were narrowed to 9 which were subjected to the test protocol.

Of the 9 candidate formulations tested, 5 showed improvements in the Tier 1 tests. The reaction of one of the candidates in the slow cook-off was so mild, the oven and setup were intact to the extent the same test could be repeated by just replacing the tested item with a new one.

Typical results are shown below:

All 5 of these candidates were then evaluated for sympathetic detonation in the current pallet configuration without barriers in accordance with the Tier 2 test program. The Tier 2 testing, like all other tests were instrumented with piezo pressure gages to measure

blast pressure from any explosion, deflagration or detonation. In this test, the gages were expected to differentiate between the magnitudes of the reactions as everyone expected the compositions to fail. Astonishing, the program achieved a first by passing the sympathetic detonation test with an artillery projectile with no barriers. What was even more amazing was that not one but three of the candidates passed the sympathetic detonation test.

Acceptor Bottom Witness Plate

Donor Bottom Witness Plate - Dented

Concurrent with the Insensitive Munitions testing and laboratory characterization testing of the candidates, a business case evaluation was performed by estimating any investment required: to produce these candidates in full production (non-recurring facility costs), to qualify these candidates (non-recurring unique testing/qualification costs), to load projectiles (non-recurring facility modifications and recurring unit cost per pound), to demilitarize the loaded munitions. All assessments included environment impact/remedy considerations. These data supported making the final decision on what candidate(s) to select for qualification testing and subsequent production.

On 29 November 2006, less than a year after the decision to execute the program, a meeting of the team was held with the intent of achieving a downselection to a single candidate. After several hours of reviewing performance data, IM data, cost and availability, it became obvious that there was no clear distinction between the three candidates that passed the sympathetic detonation test. For that reason, it was decided that a Phase 2 effort would be conducted before selection of candidate(s) for qualification and production. Phase 2 would conduct Tier 3 testing and further refine the producibility, lethality and cost impacts.

Phase 2 began with producing all the explosives in production size batches. With the exception of one of the candidates, the explosive batches were made on the production equipment at Holston AAP using production sources of the ingredients. Batch sizes were approximately 500 Kg. and were manufactured with no issues. Each production representative lot was shipped to Picatinny Arsenal and loaded into M795 projectiles. The equipment that exists at Picatinny Arsenal replicates, on a smaller scale, the equipment in the North American Industrial Base.

Tier 3 testing began with two of the three down selected IM fills subjected to Shaped Charge Jet Impact (SCJI) tests -- considered the greatest threat and challenge to overcome. Both of these IM fills successfully passed the Rockeye SCJI test, another "first" for the program, and another tremendous success that was perhaps thought unattainable. The reaction level was a Deflagration (type-IV) response that resulted in the projectile breaking-up into three-to-four "large" fragments along with substantial recovery of unreacted explosive.

Soon thereafter both of these IM fills were then subjected to the 81mm SCJI test (RPG7 threat), the pinnacle of threat hazards that is encountered more frequently by our Soldiers fighting in support of the GWOT. Contrary to the presumption that bulk HE-filled munitions would fail such an extreme threat, one of these two candidates actually passed the 81mm SCJI with an Explosion (type-III) response -- THE ROUND DID NOT DETONATE -- a true breakthrough for insensitivity!!

Bottom Witness Plate

The three formulations, while being evaluated for producibility and IM properties, were simultaneously being subjected to performance testing, that is, initiation reliability and lethality. Ojive sections of a M795 projectile were filled with the candidate explosives and initiated with a pressed PBXN9 supplemental charge. To obtain assurance that the initiation reliability was acceptable, the testing was performed not only at 21ºC but successfully repeated at -50ºC. The candidates were then evaluated for lethality in the water pit test at the Army Research Laboratory (ARL), Maryland. The test consists of detonating the projectiles in a pool of water and collecting the fragments.

Comparison of the fragments showed no significant differences between the candidates and the baseline TNT. Measurement of the detonation velocities added to the confidence that lethality will be equal to the baseline TNT filled projectile.

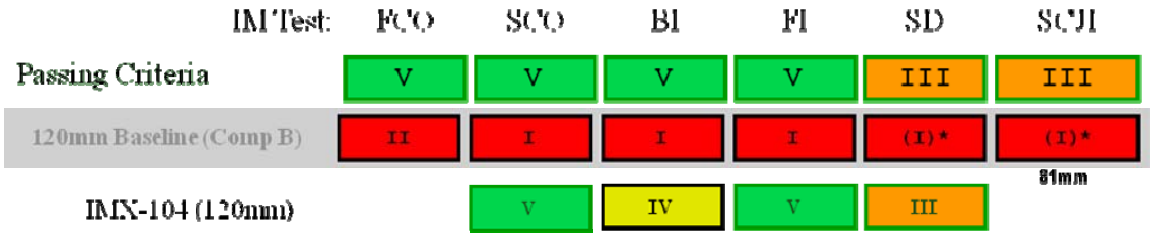
The final testing performed was the fast cookoff test on the three candidates.

The importance of these successful demonstrations -- passing SD, Rockeye SCJI and RPG SCJI for the first time -- will have innumerable benefits for the Army and USMC when incorporated into Artillery rounds. All research, development and engineering testing and evaluation to date is demonstrating an affordable, producible, reliable, environmentally compliant explosive whose performance is equivalent or better than TNT. All three are melt castable so existing facilities can be utilized to load the projectiles.

One candidate, Insensitive Munitions eXplosive-101 (IMX-101) was qualified under an aggressive schedule to achieve full scale production in FY10. The IMX-101 was selected as the candidate for qualification in 2008 and by June 2010, all acquisition of necessary test assets and all testing was completed. There was extensive testing performed on the explosive, the initiation train, and on the complete HE projectile. As with any program of this magnitude, there were issues that arose that challenged the success of the program but they were overcome by the tremendous teamwork across the Government and Industry. Further details on the qualification testing will be given in subsequent papers in this session.

Comp B Replacement

Earlier in the assessment of TNT replacement candidates, it became evident that those candidates did not have the energy levels to replace Comp B so in 2006; PM-CAS began a parallel, similar effort looking at formulations to replace Comp B. As with the M795 TNT replacement effort, simultaneous item design enhancements were made to improve the IM test performance. Again 9 candidates were chosen and subjected to a screening test in the 120mm M394A1 HE cartridge. The first phase of the screening was bullet impact, fragment impact and slow cook-off (increased heating rate to reduce the time and cost of testing). Unlike the TNT replacement effort, there was a clear distinction between the chosen candidate (IMX-104) and the other candidates, especially in the slow cook-off. The IMX-104 performed as follows:



During the review of the screening results, it was realized that the majority of mortar ammunition purchased is the 81mm family. The M821A2cosisting of a HF-1 steel body, the M734A1 MOFM fuze, a PBXW-14 auxiliary booster and a meltable fuze adapter packed three cartridges in a PA157 metal continer. Cook-off testing with the existing fuzes with existing booster pellets demonstrated acceptable results so the effort to replace the fuze boosters with an IM explosive was dropped except for the M935

where the 12 gram Comp A5 booster will be replaced with PBXW-14. Some results of the 81mm testing is shown below:

Fast cook-off

Test Setup

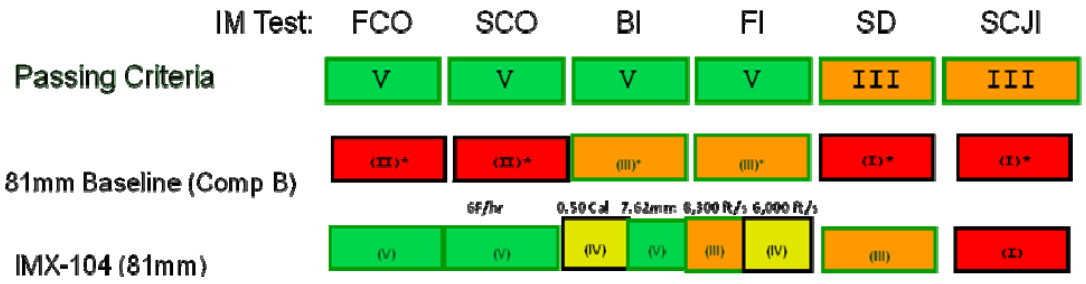
Results (Type V)

Sympathetic Detonation

Test Setup

Results (Type III)

The s IM test results obtained with the IMX-104 are given below:



As results were obtained on the engineering IM tests, PM-CAS and the USMC decided to expedite the efforts and move forward with not just the M821A2 but also with the 81mm M821A1 and M889A2cartridges along with the 60mm M720A1, M768 and M888 cartridges. Qualification of the explosive and the cartridges is scheduled for completion in 2011. The 120mm M934A1 and M933A1 HE cartridges will lag 60mm and 81mm schedules by approximately one year.

PM-CAS is committed to making safer ammunition and achieving IM to the extent it is affordable. As the Common Low-cost Insensitive Monitions Explosive (CLIMEX) effort continues to demonstrate successes, The Army and USMC are pursuing the following programs to field 11 projectiles and cartridges with significant improvements in Insensitive Munitions properties.

END ITEM	IM FILL	PROJECT START DATE	ECP DATE
155mm M795 HE Artillery Projectile	IMX-101	2006	2010
105mm M1E1 Artillery Cartridge	IMX-101	2009	2011
155mm M1122 Training Projectile	IMX-101	2007	2010
120mm M933A1 Mortar Cartridge	IMX-104	2007	2012
120mm M934A1 Mortar Cartridge	IMX-104	2007	2012
81mm M821A1 Mortar Cartridge	IMX-104	2007	2011
81mm M821A2 Mortar Cartridge	IMX-104	2007	2011
81mm M889A2 Mortar Cartridge	IMX-104	2007	2011
60mm M720A2 Mortar Cartridge	IMX-104	2007	2011
60mm M768 Mortar Cartridge	IMX-104	2007	2011
60mm M888 Mortar Cartridge	IMX-104	2007	2011

The aforementioned achievements are a testament to the tremendous teamwork across DoD and Industry, a PM-CAS & USMC Team including PEO-AMMO, Army IMB, RDECOM-ARDEC, and ARL and several industrial partners.