IM Testing Evaluation of New Melt Pour Explosive PAX-195 in Mortars

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ABSTRACT

Energetic melt-pour formulations are widely being used in U. S. DoD applications. In a majority of the melt-pour formulations, the low-melting energetic ingredient is TNT. When used as the melt phase with RDX in Comp B, it provides a powerful, inexpensive bursting charge suitable for a wide range of munitions and has been extensively employed.

It has been known that formulations containing TNT pose serious problems, such as exudation, in the field. In addition, numerous problems involving TNT are noted during the melt-pour process. Some of them are high volume-change from liquid to solid, super cooling, irreversible growth and unpredictable sensitivity. Lastly, Comp B tends to violence in accidents, making it impossible to meet insensitive munition (IM) requirements.

ARDEC worked with Air Force Armament Laboratory to develop a melt pourable formulation, using inert melt phase binder, that matches Comp B in detonation pressure and cylinder energy. Generally, binders of similar type have demonstrated certain desirable sensitivity characteristics in lower power formulations. Tests of this "upgraded to Comp B level" formulation in a heavy walled projectile show it can be loaded without problem and does retain the desired IM qualities. Further, it is competitive with Comp B in cost. Characterization data for the material and results from initial IM tests will be presented.

INTRODUCTION

ARDEC's objective was to develop a less sensitive and lower cost melt pour explosive to replace the high performance explosives currently in use. Specifically, developing a melt-castable, wax-binder system explosive having Composition B performance with reduced sensitivity towards unplanned stimuli was initiated. Program goals included the optimization of the explosive fill, designated PAX-195, with respect to metal acceleration performance, producibility, castability, and sensitivity. Explosive formulation(s) are always characterized in accordance with MIL-STD-1751A to insure suitability for usage.

We initially conducted a literature search and also evaluated IM and cost benefits being recognized in an ongoing formulation development of a lower performance explosive[1]. Many properties of this lower performance material were things that would help meet the goals of the new formulation. It was anticipated these properties could be retained if the general nature of the binder was preserved. This binder was based on types of waxes, and other inert ingredients.

Two paths emerged with potential to meet requirements for performance, IM properties and costs. Cost dictated using RDX as the energetic ingredient. One path was to extrapolate a development already underway by using a similar binder system, but with considerable optimizing so a higher RDX solids loading could be employed. The other path was to find high density, low cost, binders that were similar in important respects to the known binder that would allow performance requirements to be met with lower RDX solids loading. Target formulations for both approaches were thoroughly mapped out using thermo-chemical calculations to ensure Comp B like performance. In both cases, energetic binders were not considered because of past experience with certain of the IM tests. The higher solids path required determination of an acceptable particle size distribution and binder optimization so crystals would homogeneously mix in and the melt would pour satisfactorily. The other path required finding suitable binder ingredients that would melt at the correct temperature and become sufficiently fluid that the mix would pour at the required solids loading.

The "higher solids loading" effort developed a tri-modal RDX approach to achieve the high RDX fraction required to maintain Comp B performance using a binder reminiscent of the known binder referenced above. The formulation has a viscosity of 0.88 KP (Brookfield), which is reasonable, but is thicker than the 83 % solids formulation it was modeled after. The 83% formulation is known to be easy to pour into munitions and experience indicated there was room for some viscosity increase before loading would become a problem. Still, considerable effort went into minimizing viscosity. Binder improvements to minimize mix viscosity were incorporating liquid surfactant and a modification of wax base to minimize thermal expansion problems. The same plasticizer as before retained. Six variants of the formulation were characterized and safety and sensitivity tests were conducted. Based on the results of the testing, a further down-selection to two candidate formulations was done and these were further evaluated. A final formulation was determined, and a process developed to make pilot quantities available for large scale field testing. The final formulation had 88% RDX solids with a

NOL shock sensitivity of 175 cards. The main attribute of the final candidate was it had the lowest pour viscosity of all the candidates, yet matched the others in sensitivity characteristics. It demonstrated a performance equivalent to Composition B, with a shock and thermal sensitivity less than Comp B. Cost of the material is within 28% of the price of Comp B. The formulation was transitioned to an item program manager who arranged for certain IM tests to be done in the 60 mm and 81mm Mortar bodies. Loading these items required no significant change in procedures from usual practice.

The "high density wax binder system" approach led to a combination of chloro-wax plasticized with chloro-oil and Citroflex brand plasticizers. This combination could be blended to melt with viscosity of molten TNT at the correct temperature and still have high density. It was low cost. A significant disadvantage of Citroflex is it decreases the binder density from what is obtainable without it, so it was used sparingly. Three candidate binder systems were considered having densities of 1.54, 1.32 and 1.41 g/cc. Blends of RDX powder were prepared having calculated packing fractions of 77.8%, 78.8% and 85%. The latter, obviously, was an optimized trimodal blend. But, the 78.8% blend was about a 5/4 Class I to Class V which packed unusually well to the particular particle size distribution of the Class I material. None of these produced better than 71 wt. % solids loading, short of the desired 80 wt. %. For example, one candidate with a density of 1.41 g/cc with the trimodal blend calculated to have 162 % of the binder volume necessary to fill interstitial space in the RDX. Successful formulations using hydrocarbon waxes are being routinely made at only 140% of necessary volume; these can achieve around 79 vol. % RDX. This candidate had the lowest melt viscosity in the group, better than molten TNT. Also in this candidate's trial, only 54.6 vol. % trimodal RDX could be obtained before the pouring degenerated to something like thick oatmeal. Not a useful result. The best result of the three candidate formulations evaluated was 64 vol. %. Surprisingly, the trimodal RDX blend with a high calculated packing fraction of 85%, didn't work as nearly as well as the bimodal blend of only 78.8%. But, investigation found significant trapped air in that binder that lead to artificially inflated binder volume. Since all efforts to modify this binder system failed to reach the needed solids loading, this approach was abandoned.

IM TESTS

All IM tests were performed at Picatinny Arsenal, New Jersey. The Fragment Impact (FI) test was first performed on the 81mm Mortar. Resistance to fragment was expected to be a special feature of the formulation. Two tests were run on the 81mm Mortar; both passed the test with a Type V reaction (burn). This was the expected result. Two fragment impact tests were performed on the 60mm Mortar; both resulted in a Type IV reaction (deflagration). The increased violence was a disappointment. A noticeable difference between these two items is that the larger item is more than 50% thicker. Thus more shock passes through. Although the violent event was not shock-to-detonation transition, it was decided to improve the formulation's shock sensitivity and retest. The reformulated explosive demonstrated a 20.5 card decrease in shock sensitivity, but this did not improve the FI results.

A Slow Cook-off test was conducted on 81mm M821A2E1 Cartridges (w/ PBXW-14 booster, M734 Fuze/plastic (Formion FI-120) Fuze adapter/PAX-195 explosive fill/M220 propelling charge/M299 Ignition cartridges). The 81mm Mortar passed with a Type V reaction (burn). Again, this was the expected result form this type of formulation.

Future testing would include a Fast Cook test conducted on three (3) each - 81mm M821A2E1 Cartridges (w/ PBXW-14 boostered, M734 Fuze / Plastic (Formion FI-120) Fuze Adapter / PAX-195 Explosive Fill / M220 Propelling Charge / M299 Ignition Cartridges). The cartridges will be packed in a PA157 metal ammo container (i.e. without thermal protective covering). The test rounds can be conditioned to +145 F (overnight) prior to the FCO test. Based on experience with this family of formulations, the expectation is again a burn response. Future testing will also include Bullet Impact (BI) and Sympathetic Detonation (SD). We expect to see a Type V reaction (burn) for BI and assume that SD will result in an explosion.

DISCUSSION

The PAX-195 formulation has shown good performance so far in IM tests using the 81mm Mortar. With these good results, the 81mm Mortar should be further tested to complete the IM tests.

The quick attempt to adjust the shock sensitivity in response to the 60 mm fragment result, brought the value in the NOL LSGT down to 154 ~ 155 cards. This is close to the best that has been achieved at this performance level using PBX binder systems, yet the material is much easier to manufacture, load and demil.

The goals for the PAX-195 Melt Pour Explosive consisted of the explosive giving the same lethality performance as current Comp B (match detonation pressure and cylinder energy), reduce sensitivity to bullet and fragment impacts and perform well in other IM tests, stay compatible with present manufacturing facilities, and keep costs to a minimum. Our formulation generally meets these criteria in the 81mm Mortar. The encouraging results motivate future work, for example to address problem in thin wall shells. .Further testing still needs to be done in order to qualify the explosive, but it stands as a viable candidate to enable IM compliance for warheads now filled with Comp B.

CONCLUSION

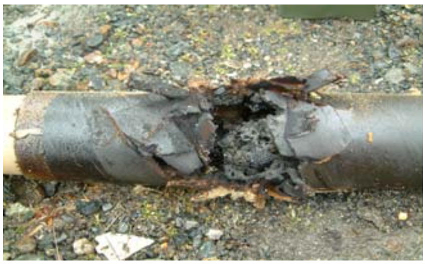
An explosive was successfully formulated that meets Composition B performance while enabling IM behavior in heavy walled shells. The cost is competitive with Comp B. There remains completing the IM evaluation and proceeding towards formal qualification of the explosive. Qualification testing must be completed on PAX-195 before it can be used as a replacement fill in Army warheads.

REFERENCES

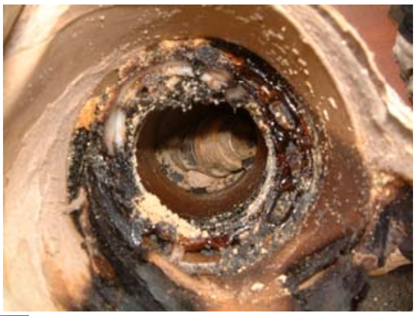
1) 1st Lt. Rebecca Ortiz, Dr. Robert L. McKenney, Jr., Dr. Thomas R. Krawietz and Mr. John F. Leahy, “The Development of PAX/AFX 194 for the 155mm Artillery Projectiles M107 and M795,” AFRL-MN-EG-TR-2002-7115, Air Force Research Laboratory, Munitions Directorate, Eglin AFB, Fl. (Nov. 2002).

FIGURES

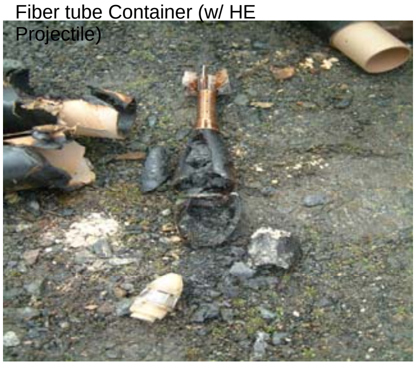
Fragment Impact Test 1 (032905)
81mm M821A2E1 Projectile w/ PAX-195 Explosive Fill & PBXW-14 Boostered Fuze



Impact Area / Burn Damage
Fiber tube Container (w/ HE Projectile)



Fuze Inside
Fiber tube Container (w/ HE Projectile)



81mm M821A2E1 HE Projectile
(After Fragment Impact)

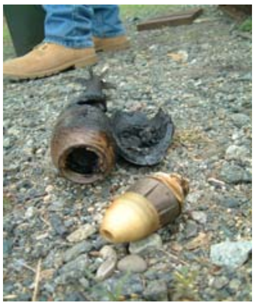
Intact Fuze
(After Frag Impact)

Figure 1: Fragment Impact Results for 81mm Mortar, Test #1 – Type V Reaction

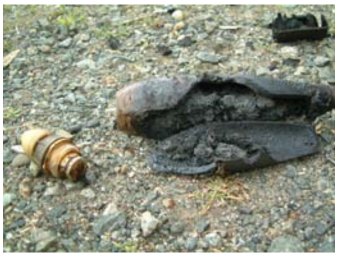
Fragment Impact Test 2 (042505)
81mm M821A2E1 Cartridge w/ PAX-195 Explosive Fill & PBXW-14 Boostered Fuze

Fuzed Projectile in Fibertube Container

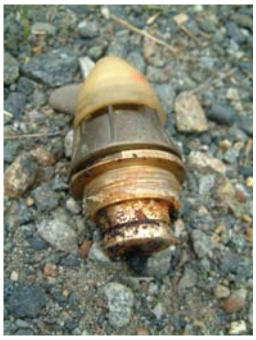
Fibertube Container w/ HE Round (Close-up View)



81mm HE Cartridge After Fragment Impact (Front View)



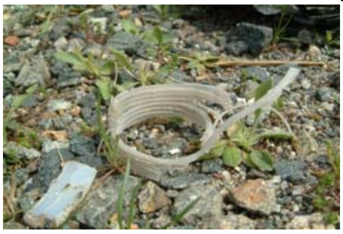
81mm HE Cartridge After Fragment Impact (Side View)



Intact Fuze (After Frag Impact)

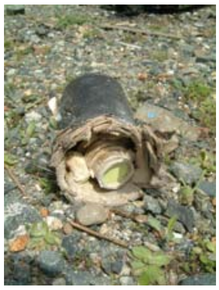
Figure 2: Fragment Impact Results for 81mm Mortar, Test #2 – Type V Reaction

Fragment Impact Test No. 1 (042605)
60mm M720A1 Cartridge w/ PAX-195 Explosive Fill & PBXW-14 Boostered Fuze

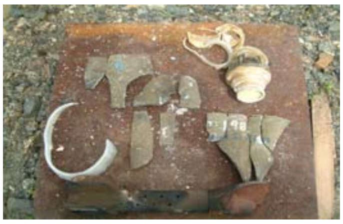


Additional Projectile Body Fragments (Recovered > 50 feet from Point of Impact)

Recovered Plastic Fuze Adapter



Intact Fuze in Top of Fibertube Container



Recovered Cartridge Fragments (and Fibetube Support Ring) After Fragment Impact

Recovered Plastic Fuze Adapter

Holes In Metal Ammo Can from Fragment Entry Hole and Projectile Reaction (After Fragment Impact)

Figure 3: Fragment Impact Results for 60mm Mortar, Test #1 – Type IV Reaction

Fragment Impact Test No. 2 (042605)
60mm M720A1 Cartridge w/ PAX-195 Explosive Fill & PBXW-14 Boostered Fuze

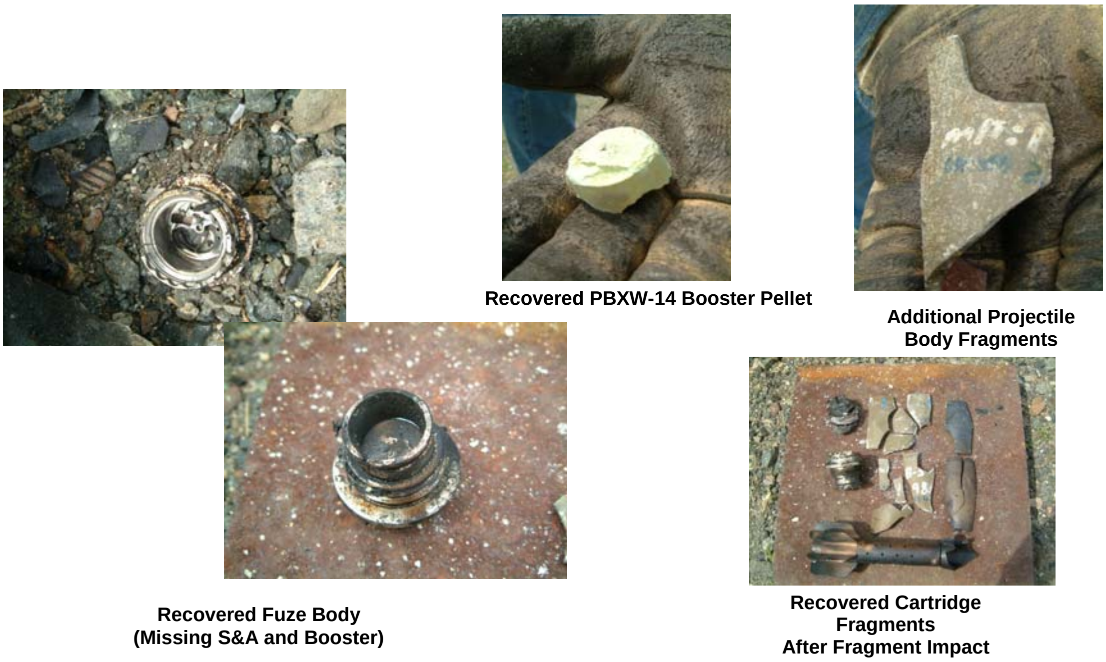
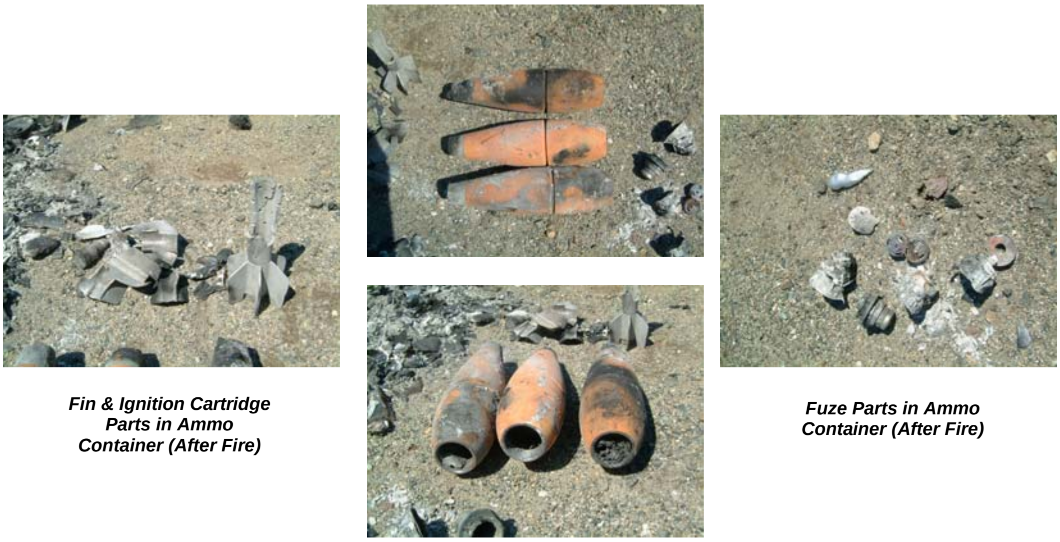


Figure 4: Fragment Impact Results for 81mm Mortar, Test #2 – Type IV Reaction

Slow Cook-off (SCO) Test (060705)
81mm M821A2E1 Cartridge w/ PAX-195 Explosive Fill & PBXW-14 Boostered Fuze



Fin & Ignition Cartridge Parts in Ammo Container (After Fire)

3- Burned-out, Intact Projectile Bodies in Ammo Container (After Fire)

Fuze Parts in Ammo Container (After Fire)

Figure 5: Slow Cook-off Results for 81mm Mortar – Type V Reaction