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US M67 – Building Blocks for an IM Compliant Item

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Executive Summary

The US M67 Fragmenting Hand Grenade is a 40 year old item with no performance requirements documentation. Due to this fact, efforts to date have been to retain the current level of performance of the existing item while improving the IM (Insensitive Munitions) characteristics. Baseline testing of the current M67 in accordance with MIL-STD 2105B (neglecting shape charge jet) have been performed. All of these tests failed with a type 1 reaction. An effort has been underway for the past 3 years to maintain output characteristics while improving the IM capability. Areas of investigation included the explosive fill, fuzing, venting technology and packaging.

The initial investigation started with the primary explosive, Composition B (Comp B). At the time this was thought to have been the primary contributor to the failure of the M67. Small scale engineering tests (bullet impact, sympathetic detonation) were performed to prove that Comp B was the main contributor of the type 1 reaction. The finding of these tests led the investigating team to the conclusion that the M213 fuze (specifically the C70 Detonator) was the main contributor to the failure, not the Composition B.

The M213 contains a primer, delay column, lead styphanate, lead azide, and a RDX booster. The primary problem with the fuze lies with its sensitivity to impact and temperature. This is due to the inline nature of the fuze and explosive material it contains. Upon determining that the M213 was the problem, a Non-Developmental Item (NDI) replacement was sought but no suitable replacement was found.

In parallel with the fuze improvement program, an explosive fill replacement effort was initiated. Of the many candidates considered, the investigating team narrowed the search down to two possible Comp B replacements: AFX PAX 196 and PAX 41. To better compare the two downselect explosives with Comp B, two types of engineering tests were performed. Pit testing (Fragment size/Quantity distribution) and Flash X-ray (Fragment velocity) were performed instead of the more expensive arena tests. While the fragment distributions for these explosives slightly differed to that of Comp B, the fragment velocities were significantly lower. This would adversely affect the lethality of the M67.

Due to the NDI failure, and the lowered performance of the explosive alternatives, a Detonator Product Improvement Program was implemented. Two innovations are planned: MEM's (Micro Explosive Initiator) Technology (borrowing from the OICW program) as well as incorporation of an out-of-line

detonator design. The MEM Investigation will be covered by a separate paper entitled, “MEMS Implementation in the M213 Fuze” which will be available at the symposium.

As a parallel effort to the detonator PIP, a meltable insert ring was investigated. The meltable insert would be placed between the neck of the fuze and mouth of the grenade. This ring was designed to melt at a temperature of approximately 200 degrees Fahrenheit. The technology was borrowed from the mortars system (Formion 120), where it has shown promise. However, the results in the M67 showed that the material was too viscous at the temperature the item was subjected to during cook off testing. Alternate materials have been investigated, which have similar physical properties but a much higher melt index (less viscous when melted). The materials being investigated are Surlyn Plastic 9970 as well as low melting point metal alloys. This technology has the advantage of being relatively cheap and adjustments can be easily be made.

Other munitions that have a similar design can benefit from the results of the M67 ongoing IM improvement program. The gamut of tests that the M67 has experienced are applicable to items that are similar in design.

1 Baseline Testing

1.1 Purpose

Military Standard 2105C defines the proper tests to run in order to become IM compliant. National Technical Systems, an independent testing company, performed the baseline testing for the M67 IM tests in accordance with Military Standard 2105B (current revision is 2105C). The baseline tests enabled the Integrated Product Team (IPT) to understand how the M67 meets the criteria of Military Standard 2105B. The following sections summarize the tests run, the test results and the IPT’s conclusions.

1.2 Test Setup and Configuration

The threat hazard assessment (THA) determined that the M67 spent 98% of the time in its full up packaged configuration. See Figure 1. The base line tests were conducted in this configuration. A full box consists of 30 M67s individually held inside of a fiber tub container.

Figure 1-1: Packaged configuration for the M67 Fragmentation Hand Grenade

1.3 Results of Baseline Testing

During the baseline testing all of the IM tests conducted resulted in a Type I (detonation) reaction. These results were studied and presented to the Insensitive Munitions Board (IMB). At the time, the consensus was that the Comp B primary explosive was the main contributor to the failure in the baseline tests.

2 Initial Investigation

The initial investigation was conducted to prove the assumption that Comp B was the primary factor causing the M67 to fail baseline testing. Engineering level tests were conducted. As a parallel effort, alternative primary explosive fills were investigated, down-selected and tested. The two candidates chosen were PAX 41 and AFX PAX 196.

2.1 Comp B – Engineering Level Tests

2.1.1 Purpose/Procedure

The purpose of the engineering level tests was to determine what part of the M67 was reacting when it was exposed to the outside stimuli described in Mil-Std 2105B. Scaled down versions of the baseline tests were conducted using both live fuzed and non-fuzed grenades. Four of the six main tests were conducted;

Sympathetic Detonation (SD), Bullet Impact (BI), Fast Cook Off (FCO), and Fragment Impact (FI). Each of the tests were conducted by using either a single grenade (BI, FCO, FI) or two grenades (SD) with each grenade being restrained and held inside standard fiber tube packaging.

2.1.2 Test Results/Conclusions

The four tests conducted yielded similar results. Each test performed with a live fuze, Comp B filled grenade detonated with the same reaction as the baseline tests (Type 1 – Detonation). When the fuze was removed and an inert fuze was place in a Comp B filled grenade, the reactions were between Type III (Explosion) and Type V (Burning).

These results were examined and again briefed to the IMB. The conclusion reached was that based upon the dramatic difference in reactions between the fuzed and non-fuzed grenades, that the fuze, not the Comp B, was the main contributor to the high order reactions. Therefore, the IPT concentrated their efforts on the M213 Fuze, rather than the Comp B.

2.1.3 Lessons Learned

During testing it is wise to remove as many variables as possible to prove the original theory. Do not implement a fix to a problem that is not there. Conduct engineering level tests on a smaller scale to prove ideas, concepts and designs.

2.2 Alternative Explosive Fill

2.2.1 Purpose

Indications that the fuze was the main contributor to the Type I reaction were not apparent when the alternative fill effort was initiated. The alternative explosive fill effort to replace Comp B was in response to the initial baseline tests which had a Type I reaction. It was believed that if the M67 was filled with a less sensitive explosive, the IM reaction would improve. The alternative explosives would also need to maintain the same performance as the Comp B they would replace.

2.2.2 Procedure

A Quality Function Deployment (QFD) was performed on the most likely candidates that were available in 2004. The QFD returned two candidates that would most likely perform to the standard of Comp B while increasing the IM performance. The two explosive the QFD produced were PAX 41 and AFX PAX 196.

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Two main set of tests were conducted. One set of tests compared the effectiveness on the IM reaction of the M67. The second set of tests compared the performance of the alternative fills to Comp B.

The first sets of tests were identical to the initial engineering level tests that determined the fuze to be the main contributor. Individual grenades were used to compare the two PAX fills with Comp B. To remove any doubt as to the cause of any possible reactions during the test, an inert fuze was used for all of the engineering tests. The tests performed were BI, FI, Slow Cook Off (SCO), and FCO.

The second set of tests performed was to compare the performance of the PAX-filled M67s to the Comp B-filled grenades. X-ray velocity measurement and Pit testing were utilized to determine the velocity and particle size. All three explosive fills were tested and the results of each test were compared.

2.2.3 Test results/Conclusions

The IM engineering level tests of alternate explosive fills did not meet with the expectations of the IPT. There was a minimal improvement when comparing the PAX filled grenades with Comp B grenades. There was no improvement when comparing the FCO and the SCO and BI. When comparing the FI results, the PAX grenades reacted with an average of a Type III, while the Comp B reacted with a Type I to a Type III.

The performance testing conducted resulted in velocity numbers that were lower for both of the PAX filled grenades. The largest decrease in velocity was about 10 percent below the velocity of Comp B. The optimal particle size is between 1 and 1.5 grains. The particle size for both PAX 41 and AFX PAX 196 differed from the Comp B. The IPT concluded that the particle size yielded from PAX 41 was better than AFX PAX 196 but neither was a similar match for Comp B.

Due to the potentially reduction in lethality, and the marginal increase in IM performance, the alternative explosive effort has been placed on hold. Due to indications that the real problem was the M213 Fuze, the IPT redirected their efforts towards investigating the energetics therein.

2.2.4 Lessons Learned

When researching alternative fills, be sure to use all resources available. There are many programs set up such as the U.S. based Insensitive Munitions Strategic Plan of Action and Milestones (POA&M) which are in place now. These resources were not available when the M67 tests were conducted.

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3 Alternative Detonator/Melt-able Insert Program

The IPT reviewed the results and concluded that new areas of investigation were warranted, both addressed the M213 Fuze. They were the Alternative Detonator and Meltable Insert. Prior to this investigation a Non Developmental Item (NDI) effort was pursued to replace the M213 altogether. However, no promising possibilities came out of this effort.

3.1 Alternative Detonator

3.1.1 Purpose/Description

The alternative detonator effort is being conducted at Picatinny Arsenal, NJ. The object is to replace the M213 detonator (C70), which contains lead styphanate, lead azide, and RDX. The current M213 has an inline detonation train as well as highly sensitive material. The new detonator will incorporate an out-of-line detonation train that will be activated by the heat created in the delay column. Presently, the alternative detonator is in the developmental stages of the design, therefore there is little test data to present. For a more in-depth review of the alternative fuze effort please refer to, “MEMS Implementation in the M213 Fuze”, a report which will be available at the symposium (personnel contacts information: written by Gartung Cheng gxcheng@pica.army.mil, Neha Mehta nmehta@pica.army.mil, and Emily Cordaro ecordaro@pica.army.mil)

3.1.2 Benefits to IM

The alternative detonator should increase the chance of surviving the impact section of the IM tests. BI, FI, and SD reactions should also decrease in severity due the out-of-line detonator and reduction of energetics in the new design. Although this new detonator should improve the impact testing, cook off mitigation will not gain any benefit. To accomplish improvements in the FCO and SCO, a venting technology must be implemented.

3.2 Meltable Insert

3.2.1 Purpose

The potential IM enhancement of the new detonator will not affect the FCO and SCO. To accomplish this, a meltable insert (Figure 3-1) must be incorporated into the M67 to quickly relieve pressure inside of the M67 body.

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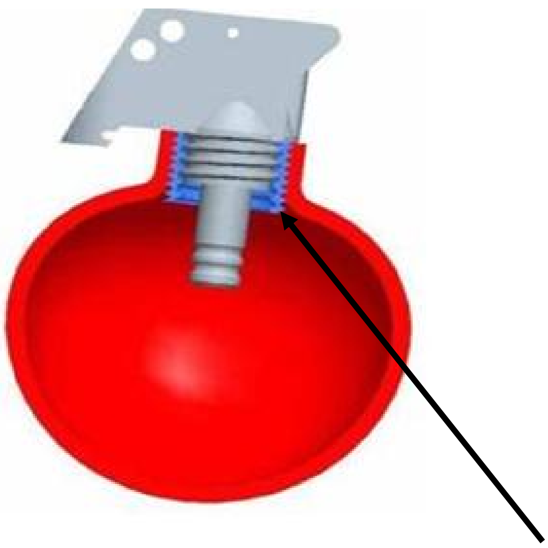

Figure 3-1: 3-D cut-away view of the M67 implemented with a meltable ring

3.2.2 Testing and Material

To test the performance of the meltable insert, a single grenade was fitted with a live fuze, a meltable ring and a Comp B-filled body. This was all placed inside a fiber tube container and simulated wooden shipping container. The wooden box simulated the packaging in the full-up configuration and allow for the heat to generate and allow the fuze and the grenade to separate.

The ring material used was Formion 120 and Surlyn 9970. These materials both exhibit a sudden loss in tensile strength when a critical temperature is reached (Melting temperature - approximately 200º F). Both materials were tested in a FCO situation. The results of the testing yielded mixed results. Some test items detonated (Type I) while others tests exploded (Type III).

It was observed that although the Formion 120 had little or no tensile strength (when melting), it was still too viscous to perform as desired. Other candidates that flow more freely are being sought such as the Surlyn 9970. Based upon the test results the Surlyn 9970 was less viscous and flowed better than the Formion 120. Tests to date have shown that implementing the meltable ring will increase the IM performance of the M67. Tests are being conducted at this time to determine the proper packing and positioning of the grenade to optimize the IM performance. To date the grenade had been positioned two ways, the fuze atop the body (Formion 120 was used) and the body atop the fuze (Surlyn 9970 was used). Both tests yielded similar results but the Surlyn proves to be a better candidate. Further investigation is needed to determine the best possible configuration.

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4 Lessons Learned

When initiating an IM effort be sure to treat the item as a system and not underestimate or overlook factors that could affect the performance and IM safety of the item. This will save time and money. This was proven by the M67 Investigation. The initial engineering level tests which helped to redirect the programs problem revealed the fuze to be the main problem.

5 Path Forward

The alternative detonator effort still maintains the highest priority on the list of IM improvements required to implement an IM compliant M67. The prototypes for the new design should be completed and tested late in FY06. Currently the meltable insert for the M67 is being retested and reviewed to ensure the best IM performance possible during a cook off situation.

6 Recognitions

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