Insensitive Munitions Analysis for 120mm Tank Ammunition

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Abstract

In recent years the U.S. Army community has become increasingly aware of the need for improvement of vulnerability characteristics during the handling, storage, and transportation of ammunition and high energetic components. Although the Department of Defense (DOD) has had an Insensitive Munitions (IM) requirement for many years, the focus on containers used for shipping and storage is very recent. This focus has been intensified by recent U.S. Navy policies for transportation of ammunition aboard naval vessels.

The Office of the Program Manager (OPM), Tank Main Armament Systems (TMAS) is currently conducting an effort to develop an IM packaging configuration for the family of 120mm Tank Ammunition that will meet the requirements set forth in MIL-STD-2105B.

The focus of the study has been to modify the current PA116 shipping/storage Container, to achieve IM performance without sacrificing its logistical efficiency and environmental protection. One method being considered is the use of a polymer vent window to serve as a pressure relief mechanism during cartridge initiation.

The testing performed to date can be categorized into two distinct areas; thermal driven events (Fast Cookoff (FCO) /Slow Cookoff (SCO)) and those that are shock driven (Bullet Impact (BI), Fragment Impact (FI), Sympathetic Detonation (SD), Shaped Charge Jet Impact Tests (SCJI). Results have been completely successful during the FCO and SCO thermal event tests and for the BI and SCJI shock event tests. While the results for the FI shock event tests have not shown the complete success shown in the thermal and other shock events, these results have been greatly successful.

Progress has been made in meeting the IM requirements and testing continues as designs are enhanced via the use of modeling and simulation.

Much progress has been made in meeting the IM requirements and final qualification testing of the selected container design is planned for the end of FY01.

Introduction

The PA116 metal ammunition container is currently utilized by the US Army for the transportation, handling, and storage (T/H/S) of 120 mm Tank Ammunition. While the PA116 provides excellent protection against the various life cycle environments that this family of ammunition encounters (i.e. temperature, humidity, shock and vibration), it reacts in a hazardous manner when its contents initiate. This paper is intended to provide an overview of recent accomplishments achieved via the use of a packaging based Insensitive Munitions (IM) design. Topics discussed will include our design approach, design optimization and qualification, test results, and conclusions. This is an ongoing effort and presently the design is considered to be a partially qualified prototype, in that it has passed FCO, SCO, BI, and SCJI but FI required costly and logistics reducing measures to pass.

Discussion

IM solutions generally fall into one of two major categories: those that reduce the sensitivity of an ammunition item's energetics to stimuli, and those that release the reaction products of ammunition in a safe manner. Historically, a significant factor in the improvement of tank ammunition performance has been realized through the use of greater energetic propulsion systems, unfortunately these systems are often more sensitive to stimuli rather than less. It is for this reason that attempts undertaken at reducing the sensitivity of the energetics fail due to an unacceptable loss in overall ammunition performance. Regarding the second category, tank ammunition is typically stored in either its packaging configuration or inside the tank ammunition racks (it is rarely left outside its shipping container when not in the vehicle). The Abrams tank provides excellent protection against initiation sources and stimuli, while at the same time employing methodology to vent the products of ammunition fires, should they occur. Therefore, the focus for this effort was in modifying the packaging container to meet the IM requirements of MIL-STD-2105B.

Design Approach

Packaging solutions have two basic requirements: release the energetic reaction products in a safe and low order manner, and maintain container integrity so that dangerous fragments are not produced. The first consideration is very important: the type of reaction an energetic exhibits is a strong function of the reaction pressure. Therefore, minimization of the container pressure during a reaction can be the difference between a deflagration reaction and simple burning. Furthermore, low-pressure reactions are generally well tolerated (structurally) by the PA116 container (see figure 1.).

FIGURE 1: Unmodified PA116 Container.

One method of maintaining low pressure during ammunition initiation is by the incorporation of pressure alleviation in the container. The approach taken in achieving this is through the use of vents about the container. These vents can be either deliberately induced defects, such as pre-scoring or notching (that are intended to provide failure locations corresponding to safe pressures), or they can be specifically designed mechanisms. The vents currently employed by this effort consist of polymer plastic inserts in the container body that are designed to either fracture or melt at a specific temperature and/or pressure (see Figure 2).

FIGURE 2: PAXXX Container with vents.

Some of the considerations that went into the design of these vents were as follows:

- Melt at a temperature safely above that which would normally be encountered during typical T/H/S, yet melt at a temperature representative of heating stimuli (FCO and SCO scenarios);
- Withstand typically encountered T/H/S shock and vibration but fracture during pressurization typical of ammunition initiation (all test scenarios);
- Provide protection against all natural and man-made environments and stimuli, including weather elements (including UV), EMI, and chemical;
- Compatibility with ammunition components;
- Manufacturing cost and producibility.
- Logistical issues

The design approach involves incorporating an adequate venting area while at the same time maintaining the structural integrity of the container. In the case of modifying the PA116, two configurations were possible: one that vented through the container ends and one that vents through the side panels. From a structural standpoint, the end venting design provides the best container strength and structural integrity. However, this design does not provide the sufficient venting area necessary to achieve the desired performance. Furthermore, venting performance is inhibited due to the necessity to expel non-energetic components that are located between the energetics and the vents. A good rule of thumb is to locate the vents as close as possible to the energetics requiring relief to avoid such interference. Through the use of modeling and simulation (Pro E and CAD), and actual testing, it was concluded that the necessary venting area and structural integrity, can be achieved with the current PAXXX (modified PA116) design by incorporating vents on the containers sides.

Another design consideration was to properly locate the relief vents, so that their orientation does not interfere with the venting of adjacent containers (while palletized), in which the reaction products are directed in the safest path. In particular, the vents on a normally horizontal container should be directed downward so that both burning and unburned propellant are ejected towards the ground rather than launched skyward.

Protection against electromagnetic interference / electromagnetic environmental effects (EMI/EEE) stimuli, bears special mention. Present (un-vented) metal ammunition containers typically provide excellent shielding against EMI. However, the incorporation of vent apertures removes a significant amount of this shielding to such a degree that this protection can be degraded to an unacceptable level. There are several options available to restore EMI protection:

- Conductive paints applied to the vent windows (copper or aluminum based, etc.). Easy to apply, but thickness in excess of a mil is required for effective shielding. Further, the potential for damage due to handling exists, and may require rework.
- Conductive foils can be adhered to either the exterior or interior of the vent windows, and satisfactory sizes (thickness) are available. Judicious selection is required, as these materials can have a noticeable effect on the vent performance (raise the container venting pressure). They also require careful placement during assembly to properly complete the EMI shielding circuit. Like the conductive paints above, exterior foils can also suffer handling damage and may require repair.
- Conductive materials (fillers) added to the polymer raw material used to fabricate the vent windows. These hold the best promise, as they do not complicate the manufacturing/assembly process, and are generally not susceptible to damage by the environment. If properly selected, they do not degrade venting performance yet provide the durability required of the vent windows.

Manufacturing and Producibility (M&P) of the design was a very important consideration when initial concepts were first being explored. By being able to continue to utilize the basic PA116 design, which has been in production for over 10 years, was paramount. It is believed that the M&P costs associated with modifying the current container design will be significantly less than if a total new design was introduced.

The final area that was considered was that of logistical impact. The current PA116 container has been successfully integrated into the US Armed Forces and Department of Transportation (DOT) logistical system, with both handling procedures and equipment in place for this configuration. The candidate IM container was designed with the following logistical goals in mind:

- Utilize the same palletization procedures and handling/transportation equipment as the current design;
- Maintain the same level of required maintenance as the current design;
- Maintain the same logistical efficiency (weight and size of palletized load, number of cartridges per pallet, etc.) as the current design.

Therefore, a design approach was chosen that emphasized modification rather than replacement of the original PA116 container. This methodology was able to retain the original features that contributed to logistical success while at the same time incorporating the changes required for satisfactory IM performance.

Design Optimization and Qualification.

After the initial design was drafted, the above parameters were balanced via iterative testing. Adjustments to the venting area, vent material thickness, etc. were made until container performance during IM testing yielded favorable results. The tests typically used to qualify an IM configuration are described in MIL-STD-2105 and consist of the following:

- Fast Cookoff (FCO) Test: simulates a direct contact exposure with a fuel fire;
- Slow Cookoff (SCO) Test: simulates slow heating due to a fire in an adjacent magazine or storage area
- Bullet Impact (BI): simulates initiation due to small arms fire
- Fragment Impact (FI): simulates initiation due to fragments from a warhead
- Shaped Charge Jet Impact (SCJI): simulates initiation due to a shaped charge jet

In addition to these tests, life cycle rough handling and storage tests are used to verify the robustness of the design. These tests are detailed in International Test Operating Procedures (ITOP) 4-2-504(2) and simulate the transportation and handling environments experienced during wheeled, tracked, and other conveyances.

Test Results.

The MIL-STD-2105 tests listed above apply heat or shock energy (or combinations of both) to the packaged ammunition item to achieve initiation.

The Fast Cookoff and Slow Cookoff tests (FCO/SCO) apply only heat energy. While the FCO utilizes a sizeable fuel oil fire as its heat source (test items completely engulfed in flame), the SCO utilizes an oven with a closely controlled heating element.

The differences in the temperatures and the rate of heat application between these two tests can produce marked differences in the reaction of both the energetics and the IM container. The FCO test was found to be the easiest to pass with the PAXXX, because of the high temperature and short heat application period required to achieve reaction. These conditions would soften and melt the vent window and exposed internal cushioning before setting off the ammunition in a point source rather than a bulk ignition (due to insufficient time for heat to migrate into the charge). In the case of the SCO, the gradual heating provided significant softening of the vented windows and internal cushioning, yet produced a more significant reaction in the energetics, as the entire charge was very close to its bulk ignition temperature when the reaction did occur. For both the FCO and SCO tests, the results were considered acceptable in that the container remained intact and no harmful fragments were expelled during the reaction.

The Bullet Impact (BI) tests apply a combination of both heat and shock energy to the test item. Testing was conducted with both 7.62 mm and 0.50 caliber Armor Piercing Ammunition. While originally believed to be just a shock event, the observation of several test items reactions showed a noticeable initiation delay (1-2 seconds) that would lead one to believe that heat transfer from a hot projectile can sometimes be the primary initiator. Regardless, this scenario is less favorable than a pure heat event, specifically because the vent polymer does not have the beneficial thermal softening that normally would be present during such a FCO or SCO event. The relief mechanism (vent) in this case must be able to fail mechanically at a low enough pressure so that the reaction remains low order. The PAXXX Container again performed acceptably by remaining intact and not expelling harmful fragments.

Shaped Charge Jet Impact (SCJI) tests apply shock energy to the test item. In order to condense testing, a Shaped Charge, larger than was specified in Mil-Std-2105B was used. SCJI has different acceptance criteria than all the other IM tests discussed in this section. As in previous IM tests, the PAXXX Container again performed acceptably.

Fragment Impact (FI) tests apply high shock energy to the test item. FI testing is considered to be an extreme test, which most items do not pass. Initial FI testing on the standard PA116 Container, resulted in an extremely violent reaction throwing hazardous fragments great distances. While without additional costly and logistical reducing modifications, the PAXXX could not deliver the completely successful results in FI that the design demonstrated in the other IM tests. The PAXXX design however showed a tremendous improvement over the PA116, by greatly reducing the amount of harmful fragments expelled, and the distances these fragments traveled.

Conclusions.

To bring the PAXXX Container from concept to present level, providing IM performance and environmental protection to 120mm Tank Ammunition, without sacrificing its logistical efficiency, required extensive testing and constant design modifications. PM-TMAS, The Army IM Board, and The Tri-Service (Army, Navy & Air Force) IM Board were extremely pleased when briefed with the IM test results achieved by only modifying the existing 120mm Tank Ammunition Packaging and without the need to modify the ammunition, thus not compromising the ammunitions level of lethality achieved. The IM Boards have also stated, based on the test results seen, an IM waiver would be approved for the less than completely successful test results in Fragment Impact (FI). This is because FI is considered to be a severe test, the PAXXX has shown a tremendous improvement over the PA116 and any modifications to the PAXXX that passes FI are costly and logistical reducing. In summary,   our soldiers (and those civilians) who handle, store, transport and are around 120mm Tank Ammunition packaged in the PAXXX are safer than those packaged in the PA116, should the energetics be initiated in any way.