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IM Baseline Testing of the XM25 HEAB Cartridge

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(U) The XM25 Counter Defilade Target Engagement (CDTE) is a shoulder-fired weapon system that will provide Infantry Soldiers with an improved capability to engage exposed/defilade personnel targets. It will allow Soldiers to acquire targets day or night using a fire control system that includes an optical and thermal imaging system and laser rangefinder to engage targets with a family of 25mm ammunition. The cartridges now available for use in the CDTE are the XM1083 High Explosive Airburst (HEAB) and XM1081 Target Practice (TP) rounds. The XM1083 HEAB cartridge is the first medium caliber warhead in a non anti-armor configuration. XM-25 represents a next generation of medium caliber technology that provides airburst capability. This is the first technology demonstration for airburst medium caliber munitions. Formal baseline IM tests of the packaged configuration were conducted and results are presented. The program office plans to assess the propulsion contribution to the reaction violence against FI and SCO, and supports demonstration of mitigation technologies in order to address these IM gaps.

Introduction

The XM25 Counter Defilade Target Engagement (CDTE) is a shoulder-fired weapon system that will provide Infantry Soldiers with an improved capability to engage exposed/defilade personnel targets. The cartridges now available for use in the CDTE are the XM1083 High Explosive Airburst (HEAB) and XM1081 Target Practice (TP) rounds. Both the TP and the HEAB rounds contain approximately 1.2 grams of commercial off-the-shelf shotgun propellant. The XM1081 TP has an inert warhead with similar geometry to the HEAB round.

Previously, the Integrated Product Team (IPT) conducted engineering level single round IM testing and achieved a response of Type (III) reaction for Slow Cookoff (SCO) and a Type (III/IV) reaction response for Fast Cook-Off (FCO) for the HEAB round. More recently, final baseline IM tests for the packaged XM1083 HEAB cartridge were conducted and the Army Insensitive Munitions Board (AIMB) scored results are in Table 1 below. Both SCO and Fragment Impact (FI) (propellant shot line) were scored as Type II. Additionally, FI testing against the explosive shot line was scored a Type III. The XM25 program office plans on conducting additional FI and SCO testing of the TP round as there is concern that the results were not representative of the TP round; TP reactions may be less severe for FI.

Table 1. 25mm ISAAS Baseline IM Test Results

Tier II Munitions Program	FCO (Config 1)	FCO (Config 2)	SCO	BI (Config 1)	BI (Config 2)	FI (Config 1)	FI (Config 2)	SR (Unconfined)	SCJ (TP only)
XM1083 HEAB	[IV]	IV	II	IV	III	III	II	P	P

Test Results

Initial IM Engineering Assessment Testing

Insensitive Munitions Engineering Assessment Testing was conducted on XM25 ammunition in CY2012 on three different types of projectiles: TP, HEAB (with metal fuze sleeve housing), and HEAB (with plastic fuze sleeve housing). The original design for the HEAB projectile had a metal sleeve; this has since been updated to a plastic sleeve in an effort to reduce cost (see Figure 2). The XM1083 HEAB round and the XM 1081 TP round are presented in Figures 3 and 4, respectively.

The Cook-Off (CO) tests conducted at Picatinny Arsenal, NJ utilized unpackaged single bare rounds, while the Sympathetic Reaction (SR) tests were conducted with two different types of packaging material within the PA108 container. The results of the SR testing were used to down-select the final packaging configuration. FI and Bullet Impact (BI) tests conducted at General Dynamics – Ordnance Tactical Systems (GD-OTS) were in the packaged configuration selected as a result of the SR engineering assessment evaluation tests.

Figure 1. Fuze housings: metal on the left, plastic on the right

Figure 2. XM1083 HEAB Cartridge (left) and warhead (right)

Figure 3. XM1081 TP Cartridge (left) and projectile (right)

Fast Cook-Off (FCO)

The fast cook off testing conducted on both the TP and HEAB round were completed IAW STANAG 4240 “Mini Fuel Fire” test protocols. There were a total of five thermocouples used for each test; two attached to the test item and three for measuring the flame temperature. The test items were supported using thick gauge cradling wires. The fuel container consisted of one welded steel fixture supporting a smaller stainless steel tray. Kerosene was used as the fuel with an acetone soaked rag and sawdust used to start the fire. The test setup is presented in figure 5.

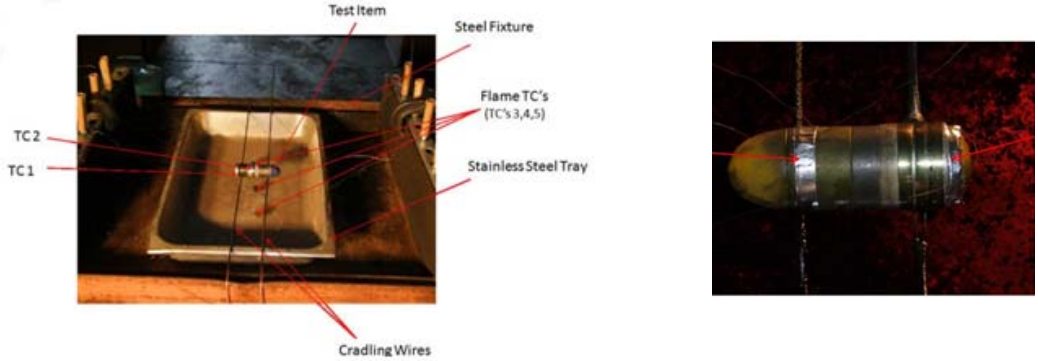

Figure 4. Test setup (left) and TC placement (right)

Figure 5. Recovered HEAB, metal sleeve

Figure 5 above shows the results of the HEAB with the metal sleeve. The main fill reacted and was consumed. The forward component reacted favorably in this case and remained intact with no

fragmentation. The aft component reacted more violently and fragmented into three main pieces and this test was assessed as a Type (III) reaction.

Figure 6 below presents results of the HEAB with a plastic sleeve. Both the forward and aft components reacted favorably and remained completely intact with no fragmentation. In addition, the plastic fuze body remained largely intact. All energetic material from both the forward and aft components were completely consumed. The aft component of the HEAB (plastic body) was located on the floor outside of the burn pan, thus the reaction was assessed as a Type (IV).

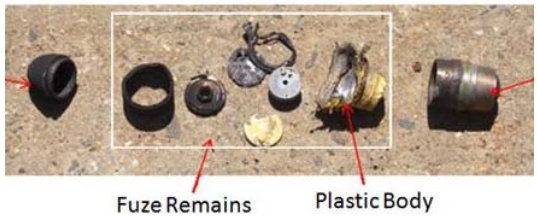

Figure 6. Recovered HEAB, plastic sleeve

Slow Cook-Off (SCO)

SCO testing conducted on both the TP and HEAB rounds were IAW STANAG 4382 "Slow Heating – Munitions Test Procedures" test protocols. There were a total of four thermocouples used for each test; three of which were attached to the test item and one measured the air temperature within the oven (Figure 8). The three thermocouples attached to the XM25 round were placed in different spots depending on which type of round was being tested.

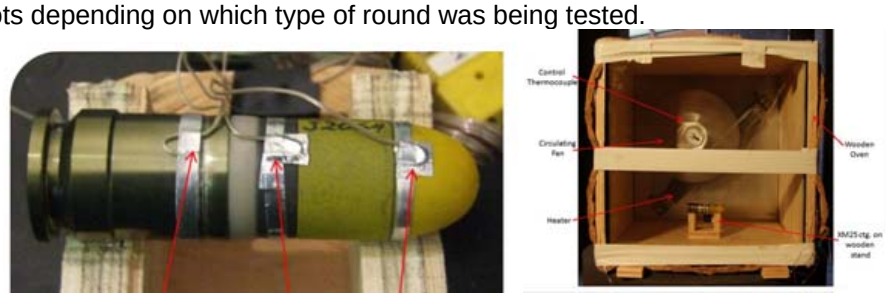

Figure 7. TP thermocouple placement (left), Oven setup (right)

In both test setups, the single thermocouple utilized to measure the air temperature within the oven was left to hang freely in front of the circulating fan to obtain the most accurate temperature reading. The first two TP tests saw the propellant initiate and send the projectile into the oven wall. Following tests on the HEAB were conducted without the cartridge case to isolate the component response.

To the right (Figure 9) are some images of the TP round during and after the SCO test. In addition to the dent from the impact of the cartridge case into the wooden side wall of the oven, the TP projectile's nose cone was dented. Due to these damages, a Type (IV/V) reaction was designated for this test.

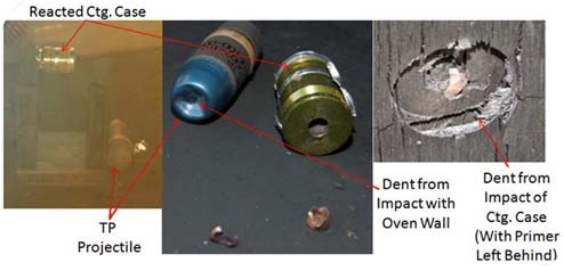

Figure 8. TP round test results

Figure 9. HEAB Metal Sleeve results – Test 1 (left), Test 2 (right)

Two SCO tests of the HEAB with metal Sleeve (Figure 10) were conducted. During Test 1, the HE within the forward component of the HEAB round reacted and was consumed, knocking the aft component out of the oven. The impact with the chamber wall severely deformed the forward component casing. However, the forward component remained wholly intact and did not fragment. Since there was no fragmentation or stress fractures on the components, a Type (IV) reaction was assessed. SCO Test 2 of the HEAB round with metal sleeve resulted in the more violent reaction of the aft component, and was assessed a Type III reaction.

SCO test of the HEAB with plastic body resulted (Figure 11) in a similar result as Test 1 with the metal body. However, the aft component had deformed due to impact. This shows that the aft component exited the oven with sufficient force and velocity to potentially travel further than 50 feet, assessing it as a Type (IV/V) reaction.

Figure 10. HEAB Plastic Sleeve results

Sympathetic Reaction (SR)

Each SR test conducted on the TP and HEAB variant of the XM25 utilized a total of six test items per test. The exact locations of the rounds varied depending on the packaging configuration; however, both configurations utilized two layers of packaging separated by a fiberboard sheet. Each test contained one donor round and five acceptor rounds. The acceptors were placed in the following positions: adjacent-1, diagonal-1, below-2, adjacent-2, and diagonal-2 (the numbers denote the top (1) or bottom (2) of the packaging. All of the rounds were painted in order to determine the severity of reaction for each acceptor placement.

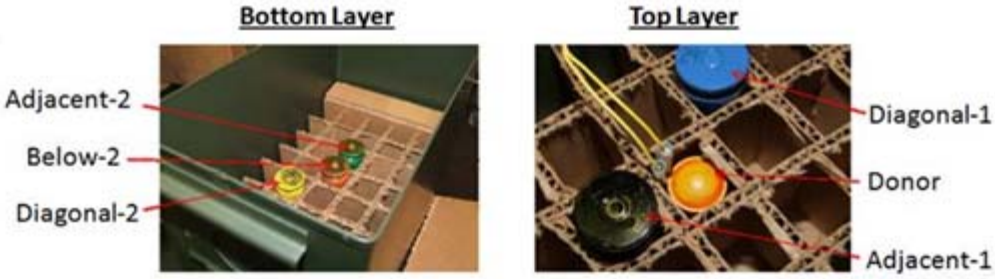

Figure 11. Sympathetic reaction test configuration 1

The HEAB round was tested in both packaging configurations, shown in Figures 12 and 13, respectively. A detonator was used to initiate the explosive train on the inside of the donor HEAB round.

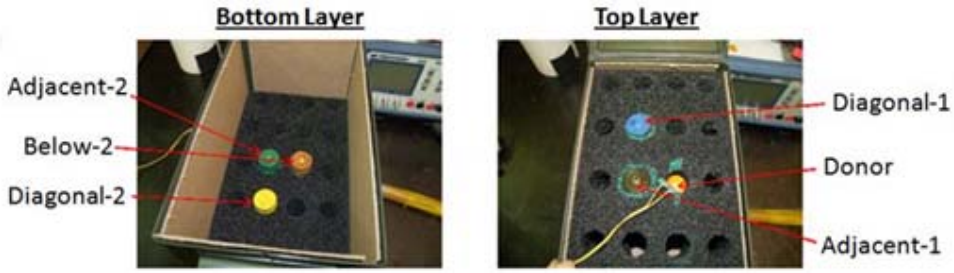

Figure 12. SR test utilizing test configuration 2

With both SR tests of the HEAB rounds, the acceptor test items reacted with an explosion reaction. Figure 14 shows the blast chamber following the SR test configuration 2, the ammunition container suffered great damage and round fragments were dispersed around the test stand. The IPT assessed these series of engineering tests as Type (III) reactions.

Figure 13. Test results from SR configuration 2 (similar results to configuration 1)

A detonator was used to initiate the percussion primer on the rear of the cartridge case of the TP SR tests. The results were assessed as a Type (V) reaction since only the donor reacted, denting the lid of the container and causing localized damage to the packaging material as can be seen in Figure 15.

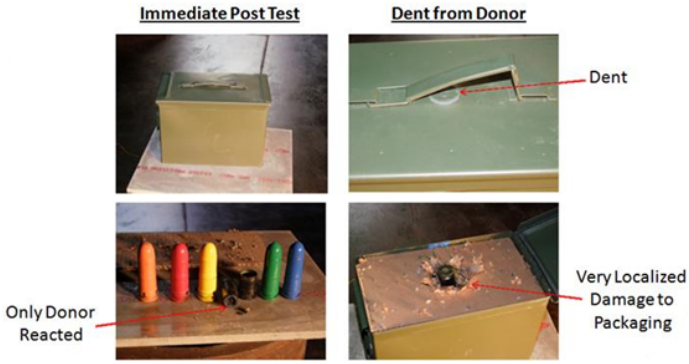

Figure 14. XM1081 TP SR test results

As expected, the severity of reaction due to SR of the HEAB rounds was much more violent (in both packaging configurations) as compared to the TP rounds.

Bullet Impact (BI)

Two tests were conducted to determine how packaged 25mm XM1083 HEAB ammunition with a metal sleeve will react when hit by three (3) M2 (.50 caliber BMG Armor Piercing) bullets in accordance with MIL-STD-2105D and STANAG 4241, Edition 2 (Bullet Impact). The BI tests were completed against a modified container loaded with eighty (80) live XM1083 25mm HEAB (metal sleeve) cartridges. The first test (Test A) was conducted with a shot line through the propellant of the cartridge. The second test (Test B) was conducted with a shot line through the HE in the aft of the cartridge. Pictured below (Figure 16) are general BI test setup images and test items aligned at two different shot lines.

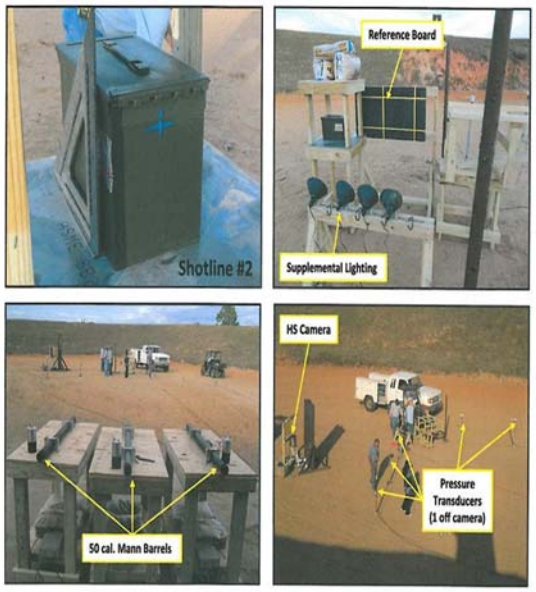

Figure 16. BI shot lines and test setup

Figure 17. Post-test results and witness plates (A=Propellant shot line; B=HE shot line)

Table 2 includes velocity measurements for these tests, (including the check-out shot), the shot location and the reaction. The velocities were all slightly higher than the STANAG. Due to the nature of engineering tests, the reactions shown in table 2 are unofficial assessments. It is

indicated from the residual debris from both tests (Figure 17) that the package did not mass detonate, as most of the individual rounds were recovered intact in and around the test arena. The witness plates from both tests showed minimal scarring. Based on the data, the preliminary scoring was assessed as a Type (V) for the propellant shot line and Type (IV) for the (HE) explosive shot line.

Table 2. Bullet Impact Test Results

Test No.	Test Date	RT No.	Shotline	Vel (ft/s)	Reaction
-	12/4/2012	12483	checkout	2926	n/a
A	12/4/2012	12484	Propellant	2920	V
B	12/4/2012	12485	Explosive	2876	IV

Fragment Impact (FI)

Two tests were conducted to determine how packaged 25mm XM1083 HEAB ammunition reacts when hit by an 18.6 grain fragment traveling at 8300fps ± 300fps. The test configuration is a metal ammunition container with 2 sets of 40 cartridges, packed nose down, for a total of 80 cartridges. The individual rounds were separated by dividers. The two boxes are offset so that the primers do not line up with the cartridges above or below. All IM tests were conducted with the bottom of the container in the down position and IAW MIL-STD-2105D and STANAG 4496 Draft 12, (Fragment Impact). The configurations and aim points were identical as that of the BI tests. FI aim points and test setup are shown in Figure 18.

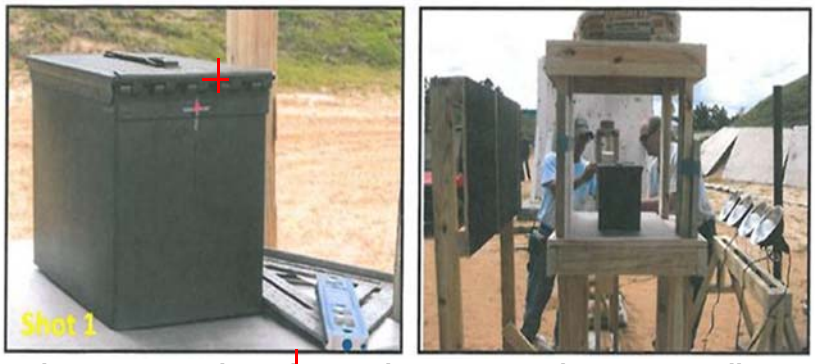

Figure 15. FI aim points and test setup: Shot 1 – Propellant

Witness plates were utilized and recovered for both tests. A single witness plate was used on the first test against the propellant shot line. The damage to the plate from the first test was minimal, so the plate was reused on the second test against the HE shot line. Figure 16 provides a side-by-side comparison of these witness plates.

Figure 16. Recovered witness plates

The state of the arena after both tests was very similar: some XM1083 rounds landed outside the test arena, having traveled more than 100 feet. The velocities shown below in the test matrix (Table 3) were within tolerance.

Table 3. FI Test Matrix

Test No.	Test Date	RT No.	Shotline	Vel (ft/s)	Reaction
1	9/12/2012	12324	checkout	8185	n/a
2	9/12/2012	12325	Propellant	8032	IV
3	9/12/2012	12326	Explosive	8290	III

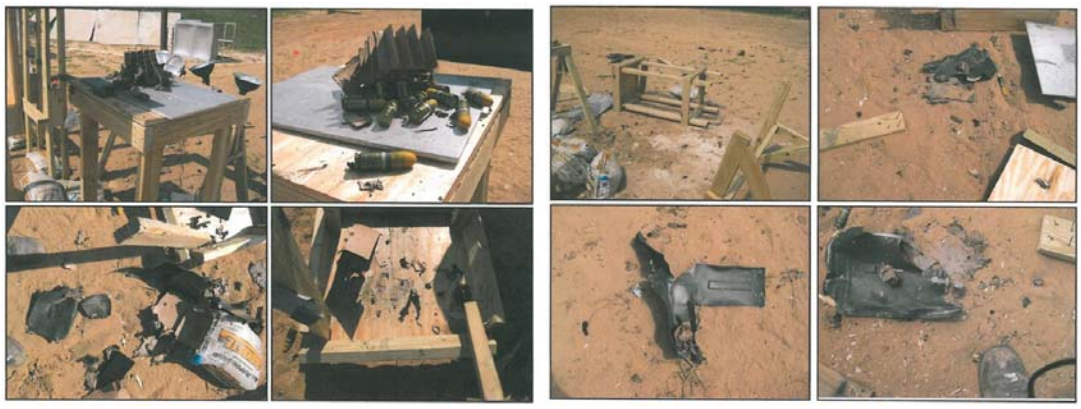

Figure 17. FI Test Results - Propellant Shot line (left), Explosive Shot line (right)

Figure 20 shows the residual debris from both tests where the packages did not mass detonate, and most of the individual ammunition was recovered intact in and around the test arena. The witness plate from Test 2 (explosive shot line) shows more scarring and slight bowing. Based on the data described above, the preliminary scores of these engineering tests was a Type (IV) for the shot line through the propellant and Type (III) for the shot line through the HE.

IM Baseline Testing

Formal baseline packaged IM tests followed the above mentioned engineering assessment IM tests. SCO, FCO, BI, FI, and SR tests of the 25mm XM1083 HEAB cartridge were completed in several test configurations, indicated below, and scored by the AIMB (Table 4).

Table 4. 25mm AIMB Scored Baseline IM Test Results

Tier II Munitions Program	FCO (Config 1)	FCO (Config 2)	SCO	BI (Config 1)	BI (Config 2)	FI (Config 1)	FI (Config 2)	SR (Unconfined)	SCJ (TP only)
XM1083 HEAB	[IV]	IV	II	IV	III	III	II	P	P

Configuration one consists of two full ammunition containers packed in a wooden crate which is then wire-bound. Configuration two features a single full container with pallet straps as shown in the image below in Figure 21.

Figure 18. Configuration two, single can (left, center) and Configuration one, two can (right)

Fast Cook-Off (FCO)

Two baseline FCO tests were conducted: Test 1 in the single can configuration and Test 2 in the two can configuration. Figure 19 below are photos taken from the single can FCO test. While the two can configuration setup photos are not shown, the setup is the same as that shown in figure 22 below.

Figure 19. Configuration Two test setup wide angle (left) and closeup (right)

The results exhibited were typical for both configurations. The test items remained on the test stand and the rounds were recovered from within the containers, which had deformed due to high temperatures. There were, however, several large holes visible in the container and some fragments were generated in both the single can configuration and two can configurations. These were scored as a Type IV by the AIMB. While the reactions were generally the same for the single and dual can configurations, thermocouple data taken from the second test (Figure 23) exhibited a great deal of signal noise and the AIMB could not distinguish flame temperature and overpressure readings. As a result, the AIMB assessed the two can configuration as a Type [IV].

Figure 20. Configuration Two Post-test results

2.1.1. Slow Cook-Off (SCO)

Two baseline SCO tests were conducted, both in configuration one (two full containers of live rounds). Per STANAG 4382 for SCO, the items were placed in an oven and soaked at a temperature of 122° F for 8 hours followed by a temperature increase of 6°F/hr. Figure 25 shows the SCO test set-up.

The first of the two tests resulted in a Type IV reaction as popping sounds were heard approximately 43 hours into the test. Shortly after the initial sounds were heard, there were visible flames within the oven and reactions lasted for 15 minutes. The post test examination revealed ejected projectiles had perforated the sides of the oven.

Figure 21. Wire bound crate w/TC threaded through a wall (left) and oven test setup in arena (right)

However, the second test with the same configuration resulted in a Type II reaction (see images below in Figure 26). Roughly 54.5 hours into the test, one can was expelled from the oven which then flamed up and rounds could be heard reacting within. A few minutes later, the expelled container exploded. Post-test examination of the witness plates showed evidence of scarring/gauging.

Figure 22. Test 2 Images: Bottom left: video capture of explosion; Top left: Oven post-explosion; Top right: recovered debris; Bottom right: Close up of witness plates

2.1.2. Sympathetic Reaction (SR)

The unconfined baseline SR test was conducted in the logistical configuration consisting of four wirebound wooden crates, each with two containers. The location and color code ID of the containers is shown in Figure 23. Due to limited supply of live test hardware, the two acceptor and one donor wirebound crates each contained one container with live rounds and one container housing inert rounds. Additionally, an inert wirebound container was included for the test. A single round in the donor can (orange) was detonated and the results were observed.

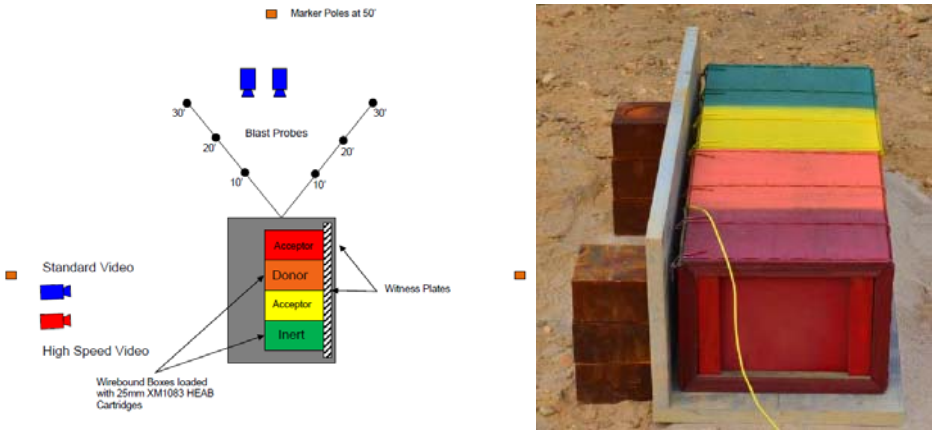

Figure 23. Color indications used for SR testing (left) and test setup (right)

The donor can split apart from the initial detonation and rounds were thrown from the can, breaking apart as they impacted the ground. The yellow and green boxes were pushed away from the donor can, but all the contents remained within the box. The red acceptor can however broke apart

causing one of the containers to be ejected with enough force to cause the lid of the can to come undone and spill its contents as seen by the Figure 24 below. The AIMB scored the test as a pass.

Figure 24. Post test pictures (left, center) and recovered debris (right)

2.1.3. Bullet Impact (BI)

Two BI tests were conducted one against the HE shot line and a second against the propellant shot line (Figure 16). The propellant shot line was tested in configuration two and the explosive shot line against configuration one.

During the first test (Configuration 2, propellant shot line) the can was propelled off the test stand upon impact from the bullet and some fragments were expelled from the can. A case and fuze sleeve was recovered and the AIMB scored this as a Type III (Figure 29).

Figure 25. Tactical Configuration post test results

Test 2 was of the two can configuration, against the HE shot line. Fireballs were visible as the bullets impacted the test item and knocked it off the stand. The images below (figure 30) show the recovered fragments. The AIMB scored the response of this configuration as a Type IV.

Figure 26. Operational Configuration, HE shotline post test results

Fragment Impact (FI)

Both the HE and propellant shotlines were tested against FI. The first of two FI tests was in configuration one and tested against the HE shotline (see Figure 31). The lid of the first container was blown off from the impact and cartridge and container fragments were scattered across the arena. There was no visible damage to the witness plate. The AIMB scored the logistical HE response to FI as a Type III reaction.

Figure 27. Configuration 1, HE shotline images: Top left: test setup; Top right: post-test; Bottom left: XM1083 rounds scattered about; Bottom right: Collected recovered debris

The second FI baseline test of a single container against the propellant shotline was scored as a Type II partial detonation reaction. The container was torn to pieces, with only a few large portions recovered, as seen in Figure 28 below. The witness plate showed damage from both the can and rounds.

Figure 28. Configuration 2, Propellant Shotline images: Post-test picture of test stand and witness plate (left) and recovered debris (right)

Shape Charge Jet (SCJ)

Two baseline SCJ impact tests were also conducted on configuration one consisting of two wire-bound containers each filled with 80 XM1081 TP cartridges. The XM1083 HEAB component is expected to fail SCJ testing, and therefore the XM1081 TP cartridges were utilized to observe

propellant reaction to SCJ impact. A steel plate was used to ensure only the jet impacted the test item as can be seen in the center image in Figure 29 below.

Figure 29. SCJ Test setup

The two SCJ tests exhibited similar results. In both cases, there was minimal damage to the witness plate, and the majority of the TP rounds were recovered from within the containers. A passing score for SCJ is a Type III reaction, or better. Based on these results, a SCJ impact against the propellant shotline for XM1081TP in configuration one was scored as a passing reaction (Figure 34).

Figure 30. Left to right: Test stand after test; container with rounds inside; Recovered TP rounds; Witness plate showing no evidence of damage

Summary

Engineering level tests were conducted in CY2012 on XM25 CDTE ammunition. XM1083 HEAB and XM1081 TP 25mm ammunition IM responses for FCO, SCO, SR, BI and FI, were assessed prior to formal baseline IM testing. SCJ testing was not part of the engineering assessment testing for the HEAB. The engineering level test results showed that the HEAB ammunition with the plastic body provided a better IM response than the HEAB with the metal body. The engineering assessed results of FCO with metal bodies were Type III/IV vs. Type IV/V with plastic and the assessed results of SCO with metal were Type III/IV vs. Type IV/V with plastic. The engineering assessed SR testing results showed that changes in packaging materials provided no additional improvement in IM response over standard packaging. Type III/IV was assessed for FI and Type IV/V was assessed for BI.

Formal baseline IM tests were conducted with packaged rounds in two configurations: Configuration One, two ammunition containers in wire-bound wooden crate; and Configuration Two, a single ammunition container, pallet strapped. Results were presented to the AIMB and scored. Nine tests were conducted, two each of FCO, SCO, BI, FI and one SR tests were conducted for the XM1083 HEAB round and two SCJ tests were conducted for the XM1081 TP round. The AIMB scored the SCJ against the XM1081 TP and unconfined SR with XM1083 HEAB as passes. Configuration One HE shotline FI was scored a Type III, however the Configuration Two propellant shotline was scored a Type II by AIMB. Configuration One HE shotline BI was scored a Type IV, but following similar fashion to the FI test. The Configuration Two propellant shotline was scored a level more severe, a Type III reaction, by the AIMB. The two SCO tests in

configuration one were scored a Type IV and Type II. Official scores take the most severe reaction, therefore XM1083 HEAB SCO reaction is officially a Type II. FCO tests were scored as a Type IV for configuration two. Due to noisy thermocouple data for configuration one, the AIMB assessed the FCO logistical reaction as a Type [IV].

Future Work

Following the formal baseline scores, IM improvements have been planned. Technologies from other medium caliber programs may be leveraged. The XM1083 HEAB cartridge would benefit from technologies implemented to vent propellant and the HE fill. Technologies may be evaluated to provide shock mitigation against impact threats. Alternatively, less sensitive explosives may also be evaluated. Packaging venting technologies may be applied to the ammunition container, as well.

The combination of energetic material and venting features will be focused on mitigating IM threats. As previously mentioned, venting is focused on releasing the primer in the aft end, and components in the front during cook-off thus preventing a pressurization of the propellant and explosive, thereby mitigating associated reaction violence. A major technical barrier is designing venting that meets launch requirements. This will be overcome by conducting structural analysis and Modeling and Simulation to ensure structural integrity of the projectile has not been compromised and that the design can meet launch requirements. The goal is to maintain its performance after IM improvements are incorporated.