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BULLET IMPACT TESTING OF AMMUNITION AND EXPLOSIVES AT PICATINNY ARSENAL

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14. ABSTRACT
A bullet impact (BI) test for evaluating the response of energetically loaded items has been established at the U.S. Army Combat Capabilities Command (DEVCOM) Armaments Center (AC) Explosive Development Facility, Picatinny Arsenal, NJ. This test capability has great utility for evaluating the insensitive munitions (IM) response of ammunition and explosive materials at any point in the design process. This test capability is relatively inexpensive and can utilize a variety of instruments and sophisticated diagnostic techniques that are not typically found when conducting BI testing. However, the confinement inherent to the test chamber precludes the collection of all data required for official IM testing. A discussion of the test setup, typical data collection, safety considerations, and opportunities and shortcomings for evaluating IM of an item is presented.

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INTRODUCTION

Bullet impact (BI) is a standard test used to assess ordnance during insensitive munitions (IM) testing, for hazard classification, and for safety evaluations. IM evaluation and scoring features a series of tests designed to quantify the response of a munition to a variety of thermal and impact threats that are possible throughout its lifecycle, such as a fuel fire and impact from fragments and shaped charge jets. The BI test is designed to simulate a small arms attack. This test is described in North Atlantic Treaty Organization (NATO) standards Allied Ordnance Publication (AOP)-39, “Policy for Introduction and Assessment of Insensitive Munitions (IM),” and AOP-4241, “Bullet Impact Munition Test Procedures,” and the United Nations “Recommendations on the Transportation of Dangerous Goods, Manual of Tests and Criteria” (refs. 1 through 3). It is required for all munitions developed and used by the U.S. military (ref. 4), as well as by NATO allies.

The standard BI test (method 1) uses 12.7-mm (.50 caliber) armor piercing (AP) M2 cartridges with an impact velocity of 850±20 m/s. Three shots are fired at a rate of 600±50 rounds per minute at a 5-cm circular target area. The munition’s response is characterized in AOP-39 using response descriptors on a scale of I (prompt detonation) to VI (no sustained reaction). The determination of the response requires extensive data collection, including cataloging and mapping the entire debris field, high-speed video, and dynamic pressure readings. The use of three bullets is to evaluate the munition’s response when subsequent bullets strike damaged material, which generally leads to a more violent response. However, the additional bullets tend to break open casings, which provides better venting, reduces confinement, and can result in a less severe response.

The IM testing for official scoring is typically performed late in the munition’s development when the design is frozen, or nearly so. Programs are encouraged to conduct subscale, engineering-level tests early in development to identify vulnerabilities when solutions can more easily be implemented. To facilitate this, engineers from the U.S. Army Combat Capabilities Development Command (DEVCOM) Armaments Center (AC) Explosive Development Facility (EDF), Picatinny Arsenal, NJ, developed an engineering-scale BI test capability for energetically loaded items. This test method is intended serve as a low-cost, highly flexible tool that can provide preliminary BI data at any point in the development cycle of a munition. It has the ability to precisely target specific locations and subassemblies of suspected vulnerability, such as fuzes and high-sensitivity booster explosives. However, this particular setup has several limitations that prevents its use for official IM scoring due to nonconformance with the prescribed test methodology and required data collection in the AOPs. The confinement of the EDF’s test chamber precludes the ability to generate and characterize a debris field or collect accurate overpressure measurements, which are critical in accurately determining and scoring the response severity. Furthermore, the current test setup only enables firing of a single bullet into the test article, not the three bullets prescribed by AOP-4241. However, the results from this test setup should be sufficient to approximate the test article’s response in a full-scale IM test.

This test was implemented primarily as a method for evaluating the IM response of an energetically loaded item, but its utility is not limited to IM testing. The EDF possesses a wide range of advanced instrumentation and diagnostics that could be used to supplement traditional BI data collection. This report will describe the BI testing capability at the EDF, including a typical test setup and data collected, safety considerations that were implemented to minimize risk to personnel and equipment, and its limitations in fulfilling IM test requirements.

DESCRIPTION OF THE TEST SETUP

The test gun is mounted on a hard stand in the instrumentation space behind test chamber 143 with the muzzle pointing into the chamber via an instrumentation port. The gun, shown in figure 1, is a universal receiver capable of accepting Mann barrels chambered up to .50 caliber in size. This gun's breech is manually operated, requiring the test personnel to hand load each cartridge, and is fired by pulling rearward on an arm that latches into the firing mechanism in the breech block. The arm is pulled by a steel-braided firing cable that is activated by a solenoid-operated pneumatic piston on the hard mount. The firing unit requires compressed air and an electronic signal to fire, both of which are controlled remotely.

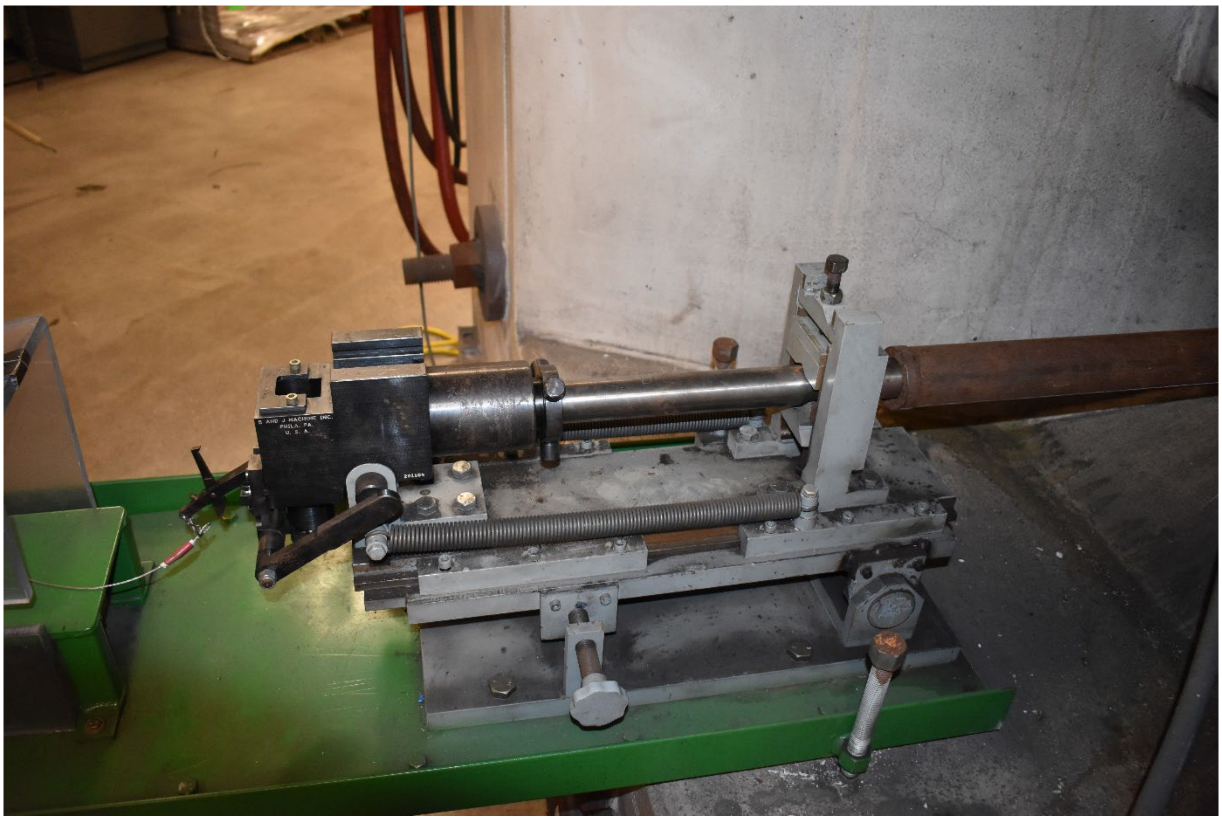

Figure 1
Test gun mounted and aimed into test chamber 143

Figure 1 shows the arm with the attached firing cable unlatched from the firing mechanism and the breech lever forward in the open position. Note the sleeve over the barrel that is connected to the instrumentation port. This prevents the gun and instrumentation from being exposed to overpressure and fragments during a shot. The shot line is established using a laser bore sight that is calibrated using alignment shots against an inert target.

The test chamber is rated for a net explosive weight equivalent to 15 lbm of trinitrotoluene (TNT). Each shot is set up to protect the chamber from fragments and the bullet to the greatest extent possible without compromising data collection. To accomplish this, the test article is typically placed inside a large diameter, thick-walled steel tube, which is referred to as a firing pot. The firing pot has a window cut in the side to allow the bullet to strike the target. Figure 2 shows an M67 grenade inside a firing pot; note the laser dot on the fuze from the gun's bore sight. The test article is backstopped by a series of armor-grade steel plates to prevent damage to the chamber in a scenario where the bullet misses or passes through the test article.

Figure 2
View along the shot line on a M67 hand grenade inside a firing pot

The test chamber is 15 ft in diameter with the test article typically placed in the center, giving approximately 8 ft of standoff from the muzzle of the gun. The velocity of the bullet is measured using a pair of precisely spaced make screens that output to an oscilloscope. A high-speed camera is mirrored to show the top view of the test article, as a direct line of sight is blocked by the firing pot. Pressure measurements in the air would be difficult to implement during these tests due to the confinement from the firing pot and chamber. Other forms of instrumentation could be investigated based on customer needs.

SAFETY CONSIDERATIONS

When generating a deliberate risk assessment for this test, several areas of high risk to the test personnel and instrumentation were identified and mitigations were implemented. The primary hazards involve the potential for exposing personnel to the bullet, fragments, and overpressure in a scenario where the gun prematurely fires into an energetic test article. This risk was mitigated through a series of engineering and administrative controls. The foremost method for reducing the probability of an incident is the use of an interlock system that prevents power from reaching the firesets and select instrumentation. The interlock system is connected to a series of man doors with access to the test area, the test chamber door, and a key-activated control panel. The control panel is in the control room, a remote location from which all the chamber testing is controlled and monitored; all test personnel are located in this room prior to the start of a test. The solenoid that controls the pneumatic firing mechanism is connected to a power source controlled by the interlock system. The control panel key is held by the operator who loads the cartridge into the gun, ensuring that the system cannot be energized until the operator is clear of the danger zone and is inside the control room. The cartridge is not removed from the preparation room until all instrumentation setup and alignment have been completed, the test article is in the test chamber with the door closed and secured, and all other test personnel and transients are in the control room. The last steps prior to firing the gun are to provide compressed air to the pneumatic firing unit and activate the warning sirens while conducting a verbal countdown.

An additional safety feature is the use of a barrel sleeve that is integrated into the chamber's instrumentation port. The sleeve is designed to enclose the muzzle throughout the recoil cycle, minimizing blast and overpressure from the gun in the instrumentation space behind the chamber. The barrel sleeve also protects the gun and instrumentation space from fragments and overpressure from the test article should it react violently to the bullet. In addition, a polymer cover is placed over the firing cable prior to the gun being armed. This cover, visible on the left side of figure 1, is designed to prevent the firing cable from being inadvertently pulled after the cartridge is loaded and the arm latched into the breech-firing mechanism.

The firing mechanism functions such that when the cable controlled by the pneumatic firing unit is pulled, the arm connected to the firing-pin mechanism is pulled to the rear and is disengaged from the gun. A video camera is positioned to provide the test personnel with a clear view of the gun, including the arm connected to the firing pin mechanism. This allows the test personnel to determine if the firing pin struck the cartridge's primer. In the event of a misfire, or in the course of testing an energetic test article, a minimum wait time of 30 min is observed prior to opening the test chamber or entering the instrumentation space.

A standing operating procedure for this test method has been fully approved. Testing of inert and energetic items has been demonstrated with test items as small as a hand grenade fuze being reliably hit.

INSENSITIVE MUNITIONS TESTING

The BI test setup at the EDF has great utility for evaluating energetic items subjected to impact from a bullet, but it has several limitations that prevent its use in official IM testing that is intended to be scored. NATO Standard AOP-4241 stipulates the use of .50 caliber AP cartridges with an impact velocity of 850±20 m/sec. This test gun is capable of firing .50 caliber AP rounds, as well as smaller cartridges and a wide variety of ammunition types. Furthermore, the ammunition could be modified to match the desired impact velocity. However, this test setup can only accommodate single shots, whereas AOP-4241 stipulates three rounds fired with a cadence that equates to a firing rate of 600±50 rounds per minute.

In addition, AOP-4241 describes an extensive list of data that needs to be collected. Several key pieces of this data can be collected during this testing, including the velocity of the bullet at impact, high-speed video of the response, and a description of the response including the recovery of fragments and debris. However, testing inside these chambers precludes the collection of several key elements of the required data, including blast pressure in two orthogonal directions with at least three gauges in each direction, mapping of the debris field, and an audio recording of the event.

CONCLUSIONS

A bullet impact (BI) test has been successfully implemented for use with energetically loaded items. A variety of safety features were implemented to minimize risk to personnel and equipment during this testing. This test is predominantly intended for simulating small arms threats as described in insensitive munitions (IM) test standards, but it can be used for other purposes due to its flexibility in bullet caliber and type. The BI testing conducted in the U.S. Army Combat Capabilities Development Command (DEVCOM) Armaments Center (AC) Explosive Development Facility, Picatinny Arsenal, NJ, can be performed on energetic items ranging from small quantities of bare energetics through full munitions, but the confinement inherent to the test chamber precludes official IM scoring due to the inability to develop a debris map and accurately record reaction pressures.

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1. NATO Standard AOP-39: Policy for Introduction and Assessment of Insensitive Munitions (IM), Edition D, Version 1, November 2018.

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