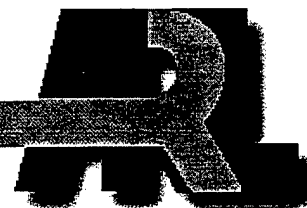


ARMY RESEARCH LABORATORY



Shock Testing of Pyrotechnic Actuators

Michael S.L. Hollis

ARL-TN-109

MAY 1998

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Army Research Laboratory

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Shock Testing of Pyrotechnic Actuators

Michael S.L. Hollis

Weapons and Materials Research Directorate

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Abstract

A primary task of the Advanced Munitions Concepts Branch (AMCB), Weapons and Materials Research Directorate, U.S. Army Research Laboratory, is to conceive unique munitions for tomorrow's weapons systems. Some of this design work has been focused on improving the accuracy of the existing stockpile of artillery projectiles and mortars. One of the critical constraints was to improve the existing stockpile of projectiles without requiring modifications. One approach has been to provide improved range control through modification of the fuze or to add a module that would fit between the fuze and the projectile body. These designs entail mechanisms that must survive 15,000 g's of set-back forces attributable to the cannon and mortar launch. If the projectile is spin stabilized, the projectile can experience $150,000 \text{ rad/s}^2$ angular acceleration and a maximum spin rate of 300 Hz. Some of the mechanisms use an off-the-shelf actuator as an integral part of a locking mechanism. The locking mechanism, although different from one design to another, is required to keep control surfaces from deploying until the desired time in flight. The volume constraints, power budget, and possible loading conditions require the actuator to be very small, rugged, and powerful without using much electrical energy. Pyrotechnic-actuated devices, which can produce a pushing or withdrawing type of linear motion, are desired. These devices are appropriately small, and they require a small amount of power to function and produce a translation with substantial force.

This report focuses on the 1MT262 retractable actuator and the 1MT172 micro-miniature piston actuator (MMPA), which are produced by Eagle-Picher Industries, Inc. Testing performed on these actuators includes shock testing to 17,000 g's, spin rate testing at 180 cycles per second, and an actual firing from an artillery cannon.

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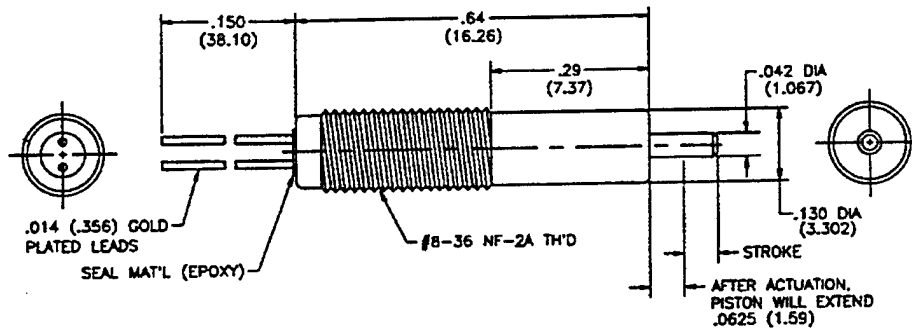
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SHOCK TESTING OF PYROTECHNIC ACTUATORS

1. INTRODUCTION

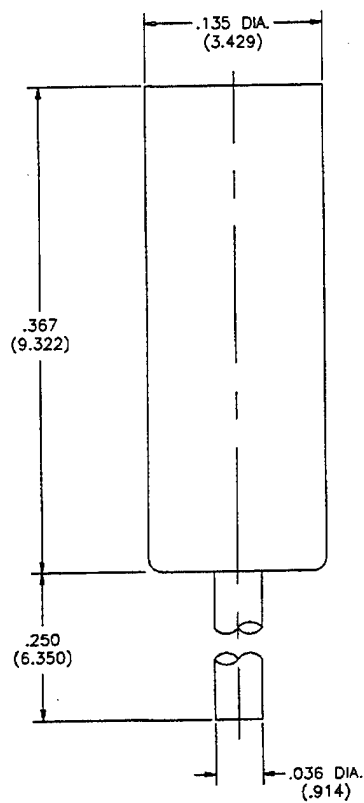
A primary task of the Advanced Munitions Concepts Branch (AMCB), Weapons and Materials Research Directorate, U.S. Army Research Laboratory (ARL), is to conceive unique munitions for tomorrow's weapons systems. Some of this design work has been focused on improving the accuracy of the existing stockpile of artillery projectiles and mortars. One of the critical constraints was to improve the existing stockpile of projectiles without requiring modifications. One approach has been to provide improved range control through modification of the fuze or to add a module that would fit between the fuze and the projectile body. These designs entail mechanisms that must survive 15,000 g's of set-back forces attributable to the cannon and mortar launch. If the projectile is spin stabilized, the projectile can experience $150,000 \text{ rad/s}^2$ angular acceleration and a maximum spin rate of 300 Hz. Some of the mechanisms use an off-the-shelf actuator as an integral part of a locking mechanism. The locking mechanism, although different from one design to another, is required to keep control surfaces from deploying until the desired time in flight. The volume constraints, power budget, and possible loading conditions require the actuator to be very small, rugged, and powerful without using much electrical energy. Pyrotechnic-actuated devices that can produce a pushing or withdrawing type of linear motion are desired. These devices are appropriately small, and they require a small amount of power to function and produce a translation with substantial force.

This report focuses on the 1MT262 retractable actuator and the 1MT172 micro-miniature piston actuator (MMPA), which are produced by Eagle-Picher Industries, Inc. The schematic of the devices is shown in Figures 1 and 2. The actuators are to be incorporated into the design of various range-correction devices for a mortar and cannon artillery. Since both platforms launch projectiles with a maximum setback load of 12,000 to 15,000 g's, the actuators must survive this load also. Eagle-Picher initially shock tested both devices at 15,000 g's for 0.8 millisecond. This report discusses the testing of these devices at ARL facilities.



DIMENSIONS IN PARENTHESIS () ARE IN MM

Figure 1. Schematic of the 1MT-262 Retractable Actuator.



DIMENSIONS IN PARENTHESIS () ARE IN MM

Figure 2. Schematic of 1MT172 Micro-Miniature Piston Actuator.

2. TEST SETUP FOR SIMULATING LOADS

The constraint for testing the actuators consisted of the axial loading of the devices with 15,000 g's. Since both devices have a hazard classification of 1.4 s, the necessary precautions were taken during testing. The 1MT262 has 18 mg of pyrotechnic and the 1MT172 has 7 mg. The inertial loading had to be in the opposite direction of the stroke of the piston for the 1MT262, and the inertial loading had to be with the stroke of the 1MT172. The 1MT262 was threaded into a small aluminum fixture that was bolted to the anvil of an Impac shock table. The leads of the device were taped to the side of the fixture. Once the device was shocked, a continuity check was performed and then the device was initiated.

The 1MT172 was tested by installing the device into an actual prototype range-correction system and subjecting it to a variety of loading conditions. The prototype range-correction system was intended to be installed onto a cannon-launched artillery projectile. This system incorporated D-shaped blades into a fuze-shaped device and was termed the "D-ring dragster module." The D-shaped blades were to extend while the projectile was in flight, thus increasing drag. The module design is discussed in more detail in ARL-MR-298 [1]. The 1MT172 is an integral part of a locking mechanism that keeps the blades retracted during launch and flight. At the desired time in flight, the actuator is initiated and the blades are unlocked. The laboratory loading conditions of the module were to survive a set-back load of 10,000 g's and a separate centrifugal loading of 210 Hz. For the set-back load, the module was adapted to the Impac shock table and shocked. The spin test required a more extensive setup. The module was installed onto the ARL (AMCB of WMRD) cantilevered roll drive and spun to 180 Hz. The 180-Hz spin rate is the maximum that the roll drive could achieve. The cantilevered roll drive, depicted in Figure 3, links an aircraft starter motor to a test fixture. Once the spin rate was achieved, the actuator was initiated. Since the actuator was located approximately an inch from the axis of spin, the spin rate test would therefore verify the ruggedness of the actuator under centrifugal forces.

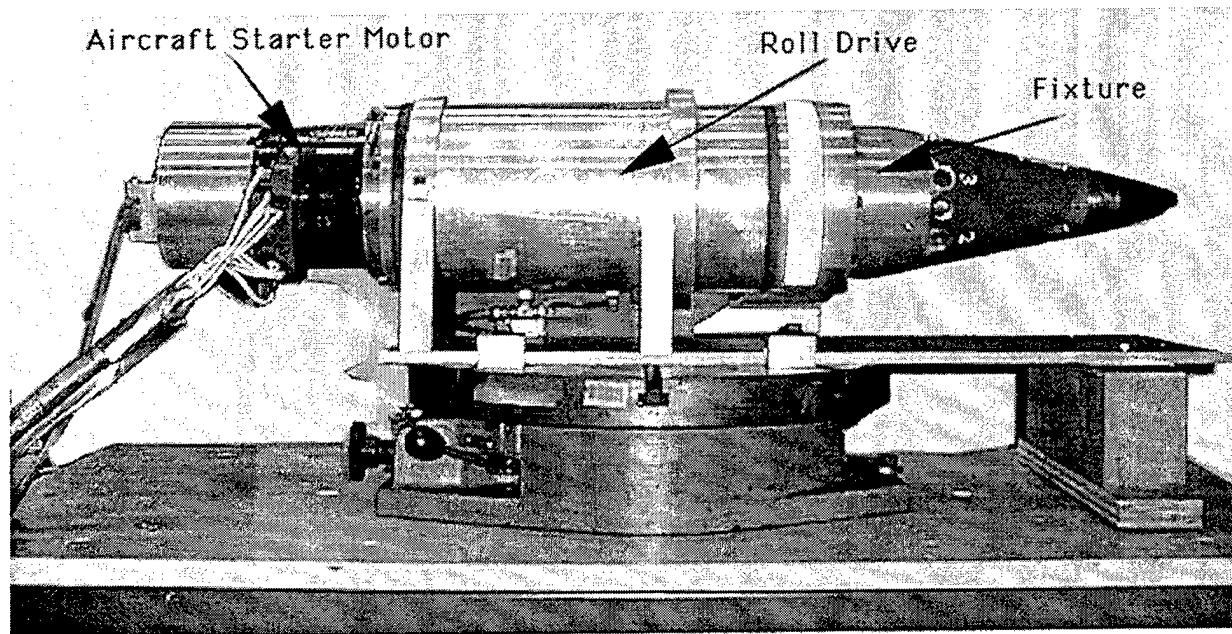


Figure 3. Advanced Munitions Concepts Branch Cantilevered Roll Drive.

3. RESULTS

Three 1MT-262 devices were shock tested. The pulse of the first device is displayed in Figure 4.

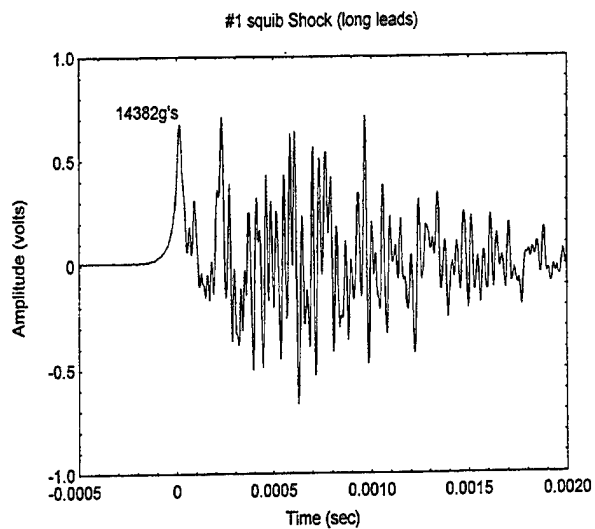


Figure 4. The Shock Pulse of the Failed 1MT-262 That Had Long Leads.

The shock loading only achieved a maximum impulse of 14,382 g's for less than 0.1 millisecond. This device failed to function after the shock test. A continuity check revealed that somewhere within the 1MT-262 was an opening in the circuit. It was thought that the long leads might have broken inside the device because of the shock load. With this in mind, we conducted a second and third test; however, the leads were cut off, leaving less than a millimeter to protrude from the device. In actual use, this device would be vacuum encapsulated in an electrical potting compound. The potting would support the leads at all points of the mortar's flight. Figures 5 and 6 depict the shock pulse during the second and third tests.

Both tests applied a 17,000-g load on the 1MT-262 devices for less than 0.1 millisecond. A continuity check was performed on each device after each shock test. Once continuity was determined, each device was then initiated.

The 1MT172 actuator performed flawlessly during the 10,000-g shock loading. In order to verify that the device had functioned after the shock event, the dragster was rapidly spun by hand. Spinning the dragster module caused the blades to eject, thus verifying that the actuator had functioned, releasing the blades. During the spin test, the actuator was initiated remotely, and the blades ejected properly. This verified the ruggedness of the actuator under centrifugal loading.

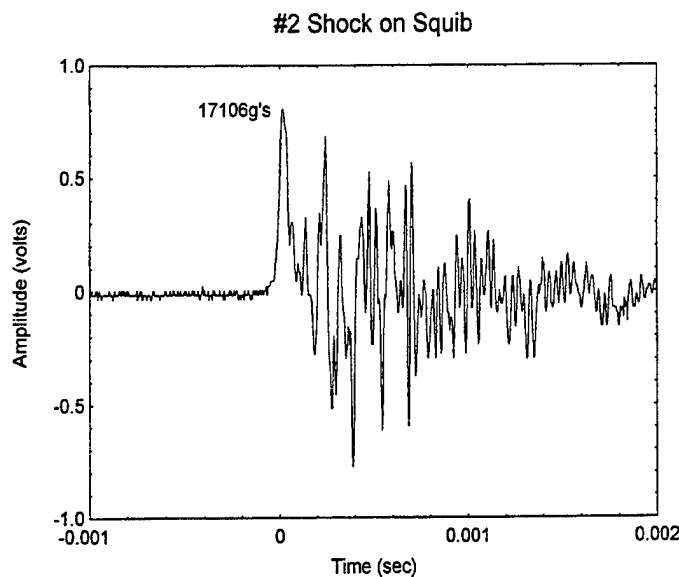


Figure 5. Shock Pulse of the First Successful Test of the 1MT-262.

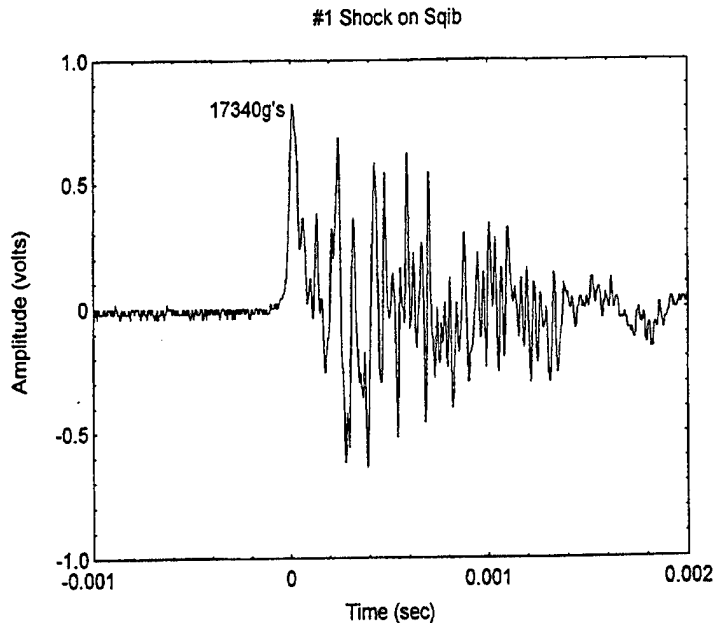


Figure 6. Shock Pulse of the Second Successful Test of the 1MT-262.

4. CONCLUSION

Based on the success of the second and third shock tests, the 1MT262 retractable actuators are sturdy enough to survive a 15,000-g shock impulse for 0.1 millisecond. Prior experiences with testing on the Impac shock table indicate that if a device can withstand the loading from the table, then the chances of the device surviving an air gun test or actual cannon launching are excellent. The air gun test and the cannon launch will apply the same load but for a longer duration such as 5 to 10 milliseconds. This report recommends the use of the 1MT262 retractable actuator in the range-correction device design for the mortar.

The dragster module shock and spin tests verified the durability of the 1MT172 MMPA to artillery-like loading conditions. The spin test alleviated concerns that the device would not be strong enough to actuate the mechanism that unlocked the blades, especially while all the mechanisms were spinning at 180 Hz. The spin test did not quantify the force output of the 1MT172, but Eagle-Picher claims that it will shear a 0.05-inch (1.27-mm)-diameter 6061-T6 aluminum pin. Because the 1MT172 MMPA performed well during the loading conditions, it was implemented at a live fire test of the prototype range-correction device during January 1997 at the National Aeronautics and Space Administration (NASA) Wallops Island test facilities. Three of four drag devices functioned successfully during the tests. This report also recommends the use of the 1MT172 MMPA in further designs of the range-correction device for artillery projectiles.

REFERENCE

1. Hollis, Michael S.L. "Preliminary Design of a Range Correction Module for an Artillery Shell." ARL-MR-298, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, March 1996.

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