

Journal of Conventional Weapons Destruction

Volume 21

Issue 3 *The Journal of Conventional Weapons
Destruction Issue 21.3*

Article 18

November 2017

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Recommended Citation

Smith, Andy and Bagley, William (2017) "Black Adder Disruptors," *Journal of Conventional Weapons Destruction*: Vol. 21 : Iss. 3 , Article 18.

Available at: <http://commons.lib.jmu.edu/cisr-journal/vol21/iss3/18>

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BLACK ADDER DISRUPTORS

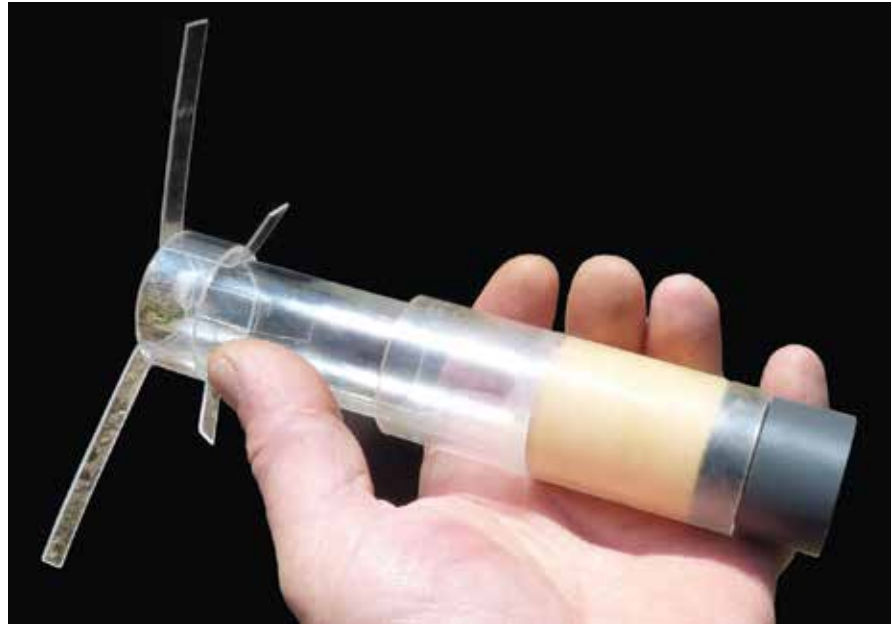
By Andy Smith [University of Genoa] and William Bagley [JOHNS HOPKINS UNIVERSITY]

This article reports on an empirical research and development project conducted in collaboration by researchers at University of Genoa, Italy, and Johns Hopkins University, United States. It is a progress report summarizing one element of a broader effort that is intended to provide explosive ordnance disposal (EOD) operators with reliable, open-source information to assist in the development of low-order munitions disruptors. Providing operators the information necessary to make energetic tools not only reduces cost but can also circumvent the restrictions and delays that often complicate the import of disruptor components.

MUNITION DISRUPTORS

The disruptors described here use an explosively formed penetrator (EFP) to breach a munitions' casing and initiate a burn of the high-explosive fill. The burn may consume the entire explosive content but more often leads to a deflagration, a partial detonation, or a full detonation. It is accepted that there is always a risk of high order detonation of the target munition so these disruptors are only used when a full detonation would be an acceptable, if undesirable, outcome.

The penetrator is formed by the detonation of an explosive charge inside the disruptor body in contact with a specifically shaped **liner**. This has the effect of focusing increased energy toward the target upon detonation, as first noted by Munroe in 1888. This phenomenon was extensively studied and exploited for use in the design of weapon systems and in explosive tunneling procedures. It was found, for example, that the geometry of the liner shape is critical for armor penetration and that adding other elements such as wave shapers inside the charge can further increase the concentration of the detonation forces. Complex liner designs are not believed to be necessary for munitions disruption purposes for which the liner is generally a simple, shallow cap of metal. On detonation of the disruptor, the liner collapses inward and is projected under immense pressure toward the target. Upon penetration of the target, the energy released should start a fire in the high-explosive (HE) content. If it burns too fast, the explosive will detonate. If it burns too slowly, the fire will be extinguished and the munition left hazardous.



The Black Adder disruptor.
 All graphics courtesy of the authors.

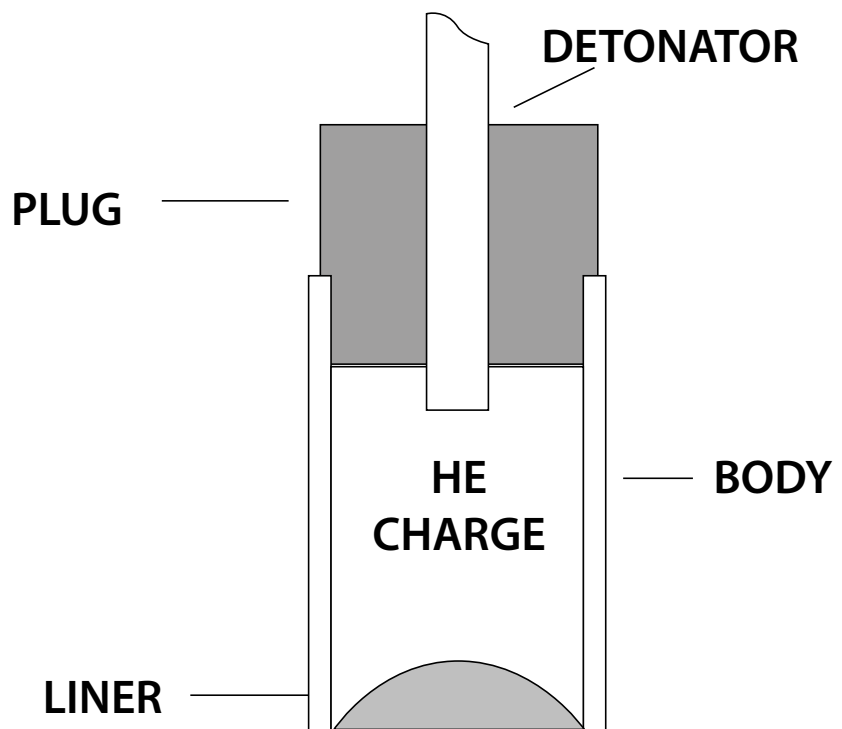


Figure 1. EFP Disruptor components.

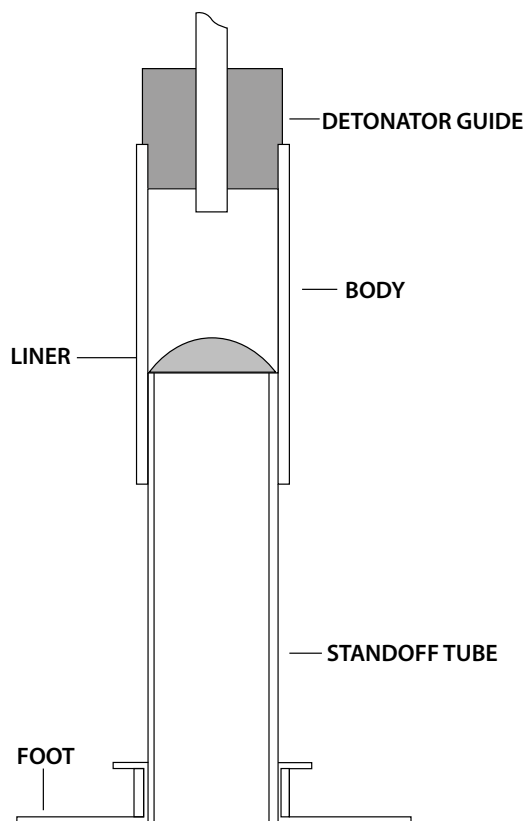


Figure 2. The Black Adder body is designed to control variables during testing.

A commonly used munition disruptor liner is a shallow cap of pressed copper, commonly called the **Baldric**. Alternatives that are intended to increase the probability of low-order neutralization success use pressed-sheet magnesium in place of copper.

To provide **controls** by which to measure success, we used simple liners of copper and magnesium. Without the time or resources to approach this with the disciplined theoretical rigor that may have been ideal, we then used an informed but informal approach to design new disruptor liners that would be low-cost, easy to make, and more reliable than those commonly used. Strictly controlling variables in empirical testing allowed rapid progress to be made.

CONTROLLING VARIABLES

It is known that disruptor reliability can be affected by the presence of air voids in the HE used to fill the disruptor in the field. It can also be affected by the distance between the disruptor and the target, and by the positioning of the detonator in relation to the liner. To control these variables during testing, we designed the simple disruptor body shown (see Figure 2).

This Black Adder body design is expensive when compared to using an off-cut of plumping pipe and wire. It was designed to control variables in liner testing rather than provide a disruptor body that is cheap to make in the field. It was our intent to control other variables as strictly as practicable so that the only variable that could alter the outcome would be the new design of liner we made.

All liners were designed to penetrate at least 10 mm of steel and deliver a payload that encourages the HE to burn. Some liner designs were highly speculative as we experimented with geometry, shaping materials, and fire-inducing payloads in a way that was intended to provide an indication of which liner would be worth continued testing.



Baldric liners.



Experimental liners.

EMPIRICAL TESTING: DAY ONE

The use of a clear, acrylic body was novel. To discover whether its failure to confine the detonation in the same manner as a steel body would cause problems, we carried out our first series of eight disruptor blast tests against inert targets.

The tests included a control to allow comparison between a standard, steel-cased Baldric disruptor and the acrylic-bodied Black Adder disruptor. Both had simple, copper-cap liners, the same stand-off and the same HE charge. The Black Adder liner penetrated the target to a greater depth and with a larger, cleaner hole than the control. It was also observed, as an incidental benefit, that the Black Adder body burned up without fragmentation, which made it less hazardous in use than a steel body.

We went on to try several liner designs but, with no reliable way of recording the spread of the liner material inside the inert target, we were not able to learn enough to make any informed comparison between the various liner behavior after entry.

EMPIRICAL TESTING: DAY TWO

Day two involved testing two control and eight unproven liner designs against inert targets. A **witness piece** that would provide a useful comparison of liner designs without using live munitions was devised and placed inside a length of 5 mm steel box section with a 5 mm steel plate on top. This arrangement required the new liner to penetrate 10 mm of steel before entering the witness piece, which then provided a useful record of the intensity and spread of burning material inside the target.

In two series of five disruptor blasts, the effects of eight unproven liners and two controls were recorded. The HE available to charge the disruptors had a lower velocity of detonation than in the original test, but the results in the series would still be valid for comparison because the



Disruptor being used against an inert target.



The witness pieces provided a valuable, permanent record of the impact and the spread of material inside the targets.



Witness piece.

charge was uniform within that test series. Analysis of the results allowed two of the experimental liner designs to be discarded and the remaining six to be ranked in order of what was believed to be their potential to produce the desired effect.

EMPIRICAL TESTING: DAY THREE

On day three, tests of the remaining experimental liners against live munitions was conducted. Generally, there is a greater chance of causing a detonation with small munitions because the point of attack with the disruptor will always be close to the fuze. Test articles

for this series were 82 mm HE mortars that had been recently manufactured. Being **factory fresh** was a detail that we hoped would ensure consistency among targets.

In each test, the feet of the Black Adder disruptor were taped in the same position on the target, and care was taken to ensure that the standoff, charge weight, and depth of detonator insertion were identical.

The copper control liner was used twice and, in both cases, the projectile penetrated both sides of the mortar casing without causing a burn or a detonation. This showed too much penetration and was an unsatisfactory result; the mortars were later destroyed using explosive donor charges.

The magnesium control liner was used twice and produced different results. In one instance, the mortar burned out and was thrown more than 100 meters away. In the other, the munition deflagrated. Both results were good, and the result provides evidence in support of the claim that a pressed magnesium cap has advantages. But the results showed inconsistency.

Four different Black Adder liner designs were then tested (two liner designs remain untested due to lack of range time). When a liner performed well, the test was repeated to ensure that the result had a good chance of



Setup showing five Black Adders prepared to fire.



82 mm HE mortar bombs.



A charged Black Adder ready to fire.



Burned out mortar shell (left) and deflagrated munition (right).



New liner one: mortar left in a hazardous condition.



An improvised and low-cost disruptor body with all of the variable control features of those used in our tests.



New liner two: deflagrated mortar (left) and burned out mortar shell (right).



New liner three: in both mortars, the HE burned to deflagration.



New liner four: an ideal result with all HE burned and no fragmentation.

being replicated. If a liner did not demonstrate the desired low-order disruption, it was not selected for additional tests.

NEW LINER ONE

In the first test using one of our experimental designs of liner, the munition was penetrated and some of the explosive filling had burned; there was no deflagration and the fuze was left in place. As this was an unsatisfactory result, the liner was set aside.

NEW LINER TWO

In the first test with liner two, the HE burned and increased pressure inside the mortar and blew off the fuze, leaving some unburned explosive loose inside an intact casing. In the second test with this liner, the munition deflagrated. This was a result very similar to that achieved with the magnesium control liner. Both results were good, but inconsistent.

NEW LINER THREE

In both tests with liner three, the mortar deflagrated cleanly and a small amount of unburned HE was expelled. This was almost the best result possible and showed consistency.

NEW LINER FOUR


In both tests with liner four, the mortar completely burned out with no deflagration. This was the best possible result and showed consistency; it was also where we ran out of time.

DISCUSSION

The test results demonstrate that using a disruptor liner to deliver a payload that encourages the explosive content to burn can have advantages in terms of effectiveness and consistency when compared with simple, metal cap-liners. Results suggest which liners performed best, but the test set was small and the limited number of tests meant that the liners included payload and architecture variables that need to be explored further. For example, the geometry of liner four is complex and may not need to be if it was actually the unique payload that achieved the desired low-order effects.

Referring back to our goals, the experimental liner materials selection criteria required that they be low-cost and not subject to shipping controls. The liners and payload ingredients could be imported without restriction or self-manufactured in any area of need. Some liner architecture is complex, and it is highly probable that similar results can be achieved with liner designs that would be much easier to make. After one or more proven liners have been selected for further development, the improvisation of disruptor bodies using large medical syringes or similarly locally-sourced material will be explored.

These results are encouraging and provide a limited set of results from which to refine the designs for further empirical testing. Only after repeated trials with consistent results will similar tests prove anything compelling about any individual liner shape or payload. This work will

continue as support permits, and we hope that a conclusion of value to field operatives can be published soon. 

See endnotes page 67

We owe a debt of gratitude to Ben Remfrey, Phil Jowett, and the staff of the EOD and Demining School at MAT Kosovo who coordinated access to demolition consumables and test range support.¹ The MAT Kosovo staff were able to arrange and oversee blast testing with a professional flexibility and patience that was greatly appreciated. We recommend the MAT Kosovo R&D support capacity to all researchers in humanitarian mine action.

Thanks also to the management and staff of the POLIEX factory and range in Berane, Montenegro.² The authors also wish to acknowledge varied useful inputs and advice from Cris Chellingsworth, United Kingdom.

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