[1]Venting Techniques for Penetrator Warheads

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By

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Background

As previously presented during the 2006 Symposium, the U.S. Air Force and Navy have been jointly researching the Insensitive Munitions program for General Purpose (GP) Bombs (2000 lb., 1000 lb., and 500 lb.) design modifications. The warheads, designated the BLU-117, BLU-110, and BLU-111 respectively were subjected to IM tests, environmental vibration, temperature & humidity, and 40-foot drop tests as defined in MIL-STD-810, MIL-STD-2105 and the appropriate NATO STANAGs.

The resulting design efforts have resulted in retaining the PBXN-109 explosive fill in the BLU-110 and BLU-111 with the addition of aft venting to allow the reactive material to deflagrate or burn rather than detonate (with the exception of one Slow Cook-off explosion for the BLU-110) in the four primary IM tests. The BLU-117 has transitioned to the wax based explosive AFX-795 with aft venting similar to the other two GP warheads. The BLU-117 configuration demonstrated burning IM reactions in the two cook-off test series and explosions in the bullet and fragment impact test series. These IM improved warheads have transitioned to ongoing procurement.

The Air Force team then began examining the BLU-109 and the BLU-122 hard target penetrator warheads as they approached new acquisition contracts as is required under US Office of the Secretary of Defense (OSD) direction to improve the IM characteristics with the goal to meet all IM criteria.

The USAF as the design activity for the BLU-109 and the BLU-122 examined technologies that would allow venting of these warheads during the IM test series. Since the explosive used in the AGM-158 Joint Air-to-Surface Stand-Off Missile (JASSM) and other penetrator weapons, AFX-757[2], is an extremely insensitive detonating substance (EIDS) this became

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[2] http://www.globalsecurity.org/military/systems/munitions/jassm.htm

a primary candidate for the BLU-109 penetrator warhead. Even though an EIDS explosive, the material, in a cook-off test series, will run-up to explosion if not adequately allowed to burn through vents. If the total vent surface is not adequate the warhead becomes propulsive and will fail the respective IM test series. The challenge was to create sufficient burn surface without sacrificing warhead survival or performance.

Warhead Closure Design

The basic BLU-109 design was maintained, but a concept of a releasing the entire aft closure plate was proposed since this method works in other IM compliant warheads. The design that emerged was to add a eutectic segment in the threaded aft closure retaining ring, as shown in figure 1.

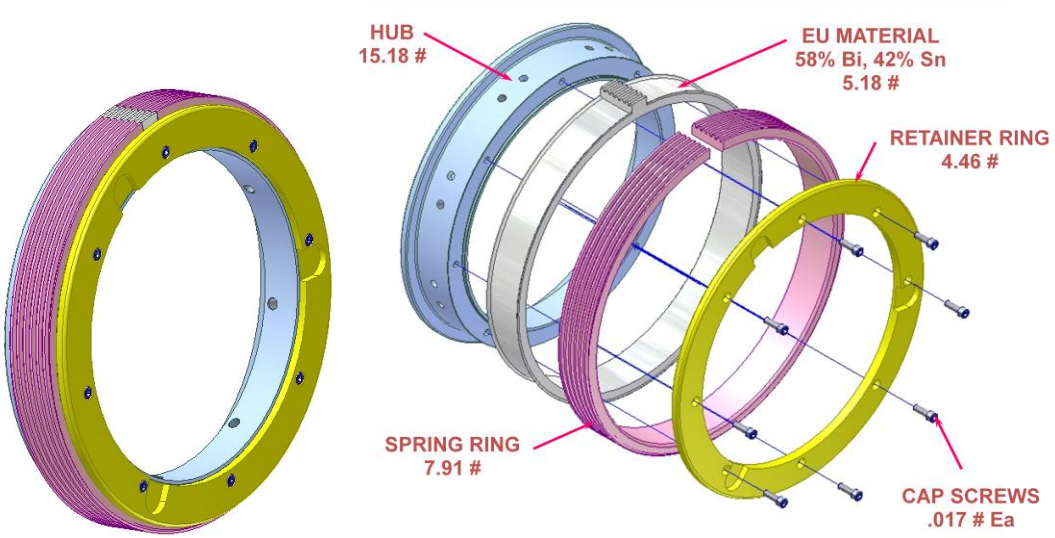

Figure 1. Eutectic Retaining Ring (Exploded View)

This is produced using a spring ring that is forced open in a fixture, molten eutectic material is then poured into the void area, and once cooled, the threads are machined into the outside of the assembly. This assembly serves the same purpose as the previous retaining ring to hold the aft closure plate in place. As the temperature rises during a cook-off event, the eutectic melts, drains away and allows the threads in the spring ring to retract out of the threads in the warhead case. This allows the aft closure to fall out of the warhead and exposes the diameter of the warhead as a burn surface. The eutectic material is commercially available under several brand names and is a mixture of bismuth and tin.

To provide early pressure relief, before the eutectic closure ring releases, especially in a fast cook-off scenario, the aft closure plate is also designed with a series of vent holes that are filled with Ultra High Molecular Weight (UHMW) polyethylene (UV stabilized) plugs.

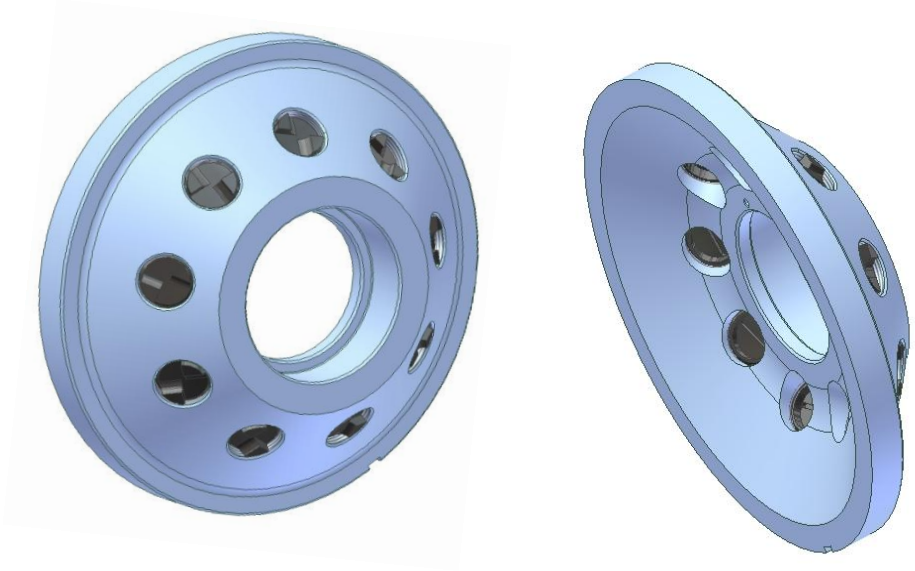

Figure 2. Aft Closure Plate with Polyethylene Plugs

Since the fuzewell is rigidly attached to the aft closure plate and to the internal conduit from the wind turbine that arms the fuze, a method was needed to allow the conduit connection in the fuzewell to separate in a cook-off scenario. Thus the nut that retains the conduit to the fuzewell was replaced by one fabricated from the same polyethylene material as the vent plugs. Although this functioned to release the conduit during testing, it was later found to be too soft or too few threads to survive all environmental extremes that the warhead may experience. It was replaced in the design with a nut fabricated from the eutectic material.

Insensitive Munitions Test Series Commences

With the enhanced venting and EIDS explosive fill (AFX-757) the design moved into the testing phase. During both fast and slow cook-off tests (STANAGs 4240 and 4382) the aft mechanism functioned as designed to minimize internal pressure and present the entire aft surface of the fill for a burning reaction. Unfortunately these tests were scored as type IV (deflagration) since large chunks of burning explosive were expelled beyond the 15 meter (50 feet) allowed by Allied Ordnance Publication (AOP)-39 and STANAG 4439.

The stability of the EIDS fill was dramatically demonstrated during the Bullet Impact test series conducted according to STANAG 4241. In each of two test events the case was penetrated by three .50 caliber type M2 armor-piercing projectiles all of which penetrated the case but resulted in no reaction of the fill material as shown in post event photos, figure 3.

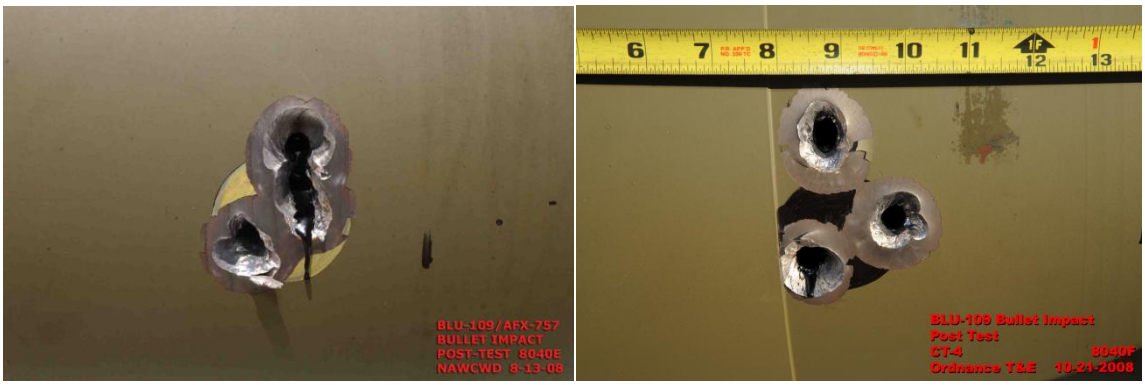

Figure 3. BLU-109 Bullet Impact Test Results

During Fragment Impact testing (STANAG 4496), one of the test articles became propulsive, resulting an overall score of Type IV (deflagration). Finally the Shaped Charge Jet test (STANAG 4526) was scored as no more severe than a Type III Explosion, resulting in a passing score.

Environmental Test Series

A basic safety test series, as required by MIL-STD-2105C, was conducted including temperature and humidity cycling, vibration testing, and 12 meter (40 foot) drop tests resulting in no significant issues.

BLU-109 Technical Data Package Delivered

With the Insensitive Munitions test results formally scored, the procurement technical data package was updated and submitted to Ogden Air Logistics Center to support official procurement.

Nose Venting Techniques

Not being satisfied with the IM cook-off results in the BLU-109, the Air Force design team began examining techniques to allow venting of the front of the explosive cavity on penetrator warheads as a possible way of preventing forceful expulsion of burning explosive during cook-off test scenarios. One suggestion was to create a large frontal plug that could be held in place by an o-ring made of eutectic material that would be pushed out by a pressure build-up in the front of the explosive chamber or expanding explosive during a cook-off scenario. This concept, illustrated in figure 4, was demonstrated on a small scale but rejected as questionable during penetration of multiple layered targets.

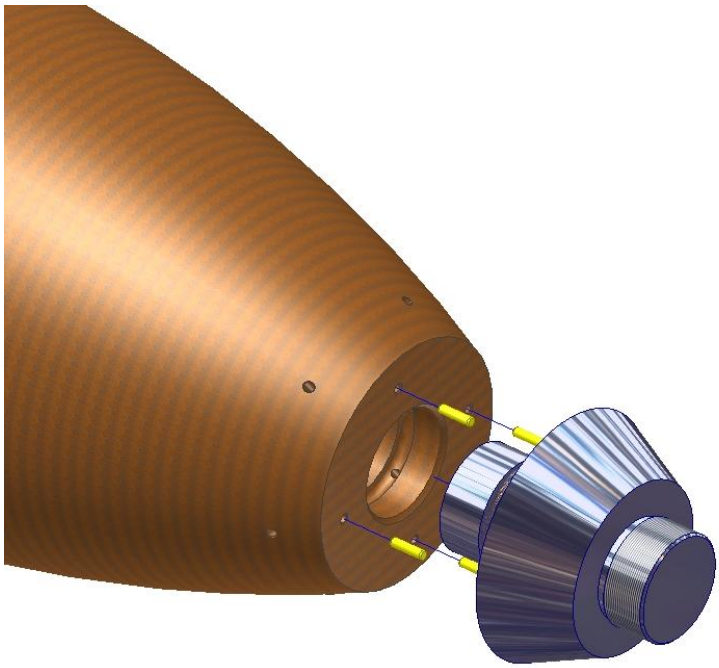

Figure 4. Single Releasing Nose Plug Concept BLU-109

An alternative design of six smaller radial holes was recommended to allow gas pressure to vent without being effected by warhead roll orientation. The concept was to fill these holes with the same eutectic material previously proven in the BLU-109 aft closure retaining ring. The concept was to pour a small reservoir of molten eutectic into the front of the empty case which would flow into the vent holes and cool as a solid portion of the nose, depicted in figure 5. This concept was rejected when analysis indicated that the heat of the molten tar liner that lines the empty case is hotter at application, 350°F (176.7°C), than the melting temperature of the eutectic material, 281°F (138°C).

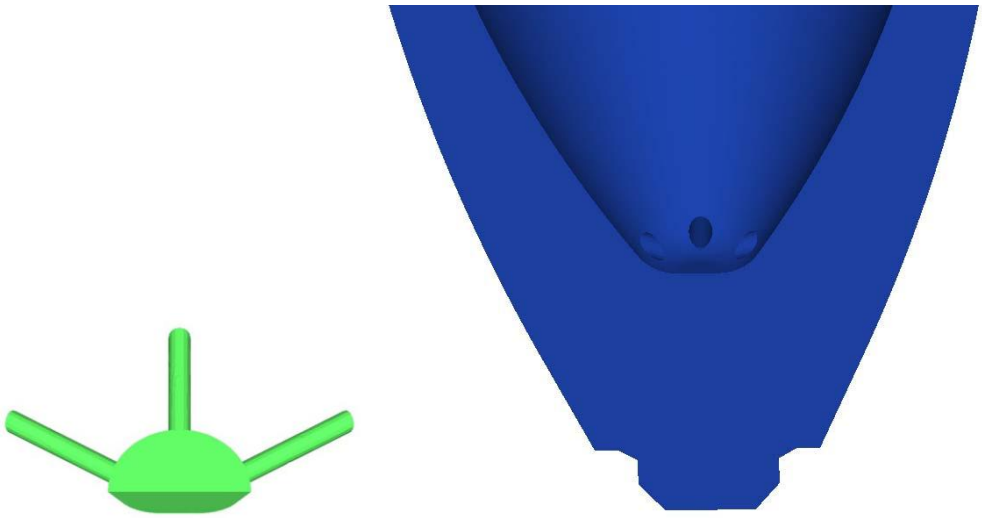

Figure 5. Original Concept of Eutectic Filled Nose Vents

Modeling was also used to determine the warhead stress in the nose area especially during oblique penetration events, shown in figure 6, and the appropriate size for the holes was analyzed. Since the first opportunity to test this design was on the BLU-122 warhead, a ¾ inch diameter sized hole was selected.

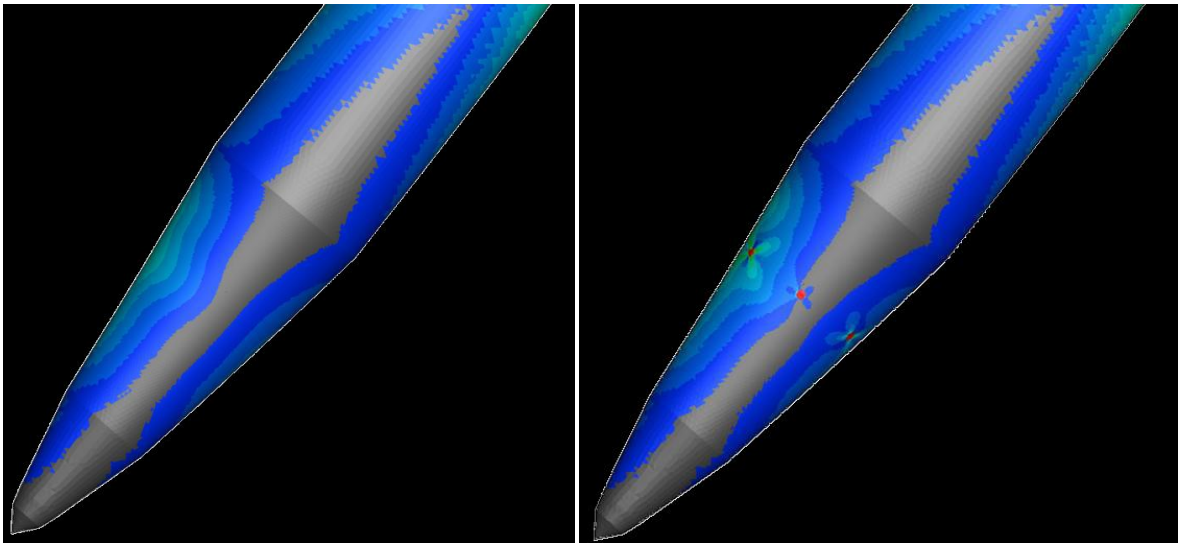

Figure 6. Modeling of No Nose Vents Versus ¾ inch Vent Holes

In the updated design, non-eutectic plugs are threaded into the holes while the warhead is tar lined. These are then replaced with eutectic plugs before the warhead is filled with explosive. As part of an IM risk reduction effort, this design was evaluated in fast and slow cook-off tests. Both of these events resulted in a Type V (burning) reaction, shown in figures 7 and 8 post mission photos.

Figure 7. Aft Closure Plate and Retaining Ring Among Ash After Fast Cook-off

Figure 8. Nose Vent Hole with Thermo Couple After Fast Cook-off

The design then advanced to sled testing to verify the integrity of the warhead case during a representative penetration event. Sled testing was conducted using an inert filled warhead and then progressed to a live filled warhead. The plug design is shown in figure 9.

Figure 9. Eutectic Plug and Post Sled Test Condition

These sled tests also incorporated the same eutectic aft closure retaining ring used in the BLU-109 design. Post mission photos in figure 10 document the survival of the nose vents and the aft closure plate during a recent sled test. These test results validated that the warhead performance was not compromised by the addition of these nose venting improvement and the aft closure plate remained in the warhead through the penetration scenario.

Figure 10. Nose Vent Plugs and Aft Closure Plate Post Sled Test Condition

BLU-122 Path Forward

Since the BLU-122/B is a recent improvement to the BLU-113 penetrator, many of the IM testing and environmental tests were accomplished in 2005. However, as a result of the risk reduction efforts recently completed, the warhead can be returned to production as a much safer IM enhanced version. The Air Force team is evaluating all previous testing and IM compliance accomplished to date and determine which testing needs to re-accomplished and formally scored for IM improved response.

Conclusions

With currently available warhead explosives, the safest means of passing the IM test series is by incorporating venting technology especially in cook-off test events. The legacy general purpose 500lb, 1000lb, and 2000 bombs have been updated with venting technology. The larger penetrator warheads have demonstrated milder IM reactions when adequate venting is provided. In penetrators this requires some method of nose venting to minimize propulsive reactions. Although the design changes have not achieved full IM compliance yet, the results represent a significant improvement over current Air Force and Navy warheads. Initial indications are that even though AFX-757 is an EIDS explosive offers improved blast performance over both current explosives but can achieve improved IM performance.

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