National Defense Industrial Association
2006 Insensitive Munitions & Energetic Materials Symposium

Advanced Precision Kill Weapons System (APKWS) IM Solutions

Zachary A. Spears*, Robert Hutcheson, and Matthew Sanford
Technology Division, Weapons Department,
Indian Head Division, Naval Surface Warfare Center,
Indian Head, MD 20640, (301) 744-1930, spearsza@ih.navy.mil

Abstract. Advanced Precision Kill Weapons System (APKWS) was designed to meet new system requirements and to improve on current Insensitive Munitions (IM) response. The current M151 warhead uses Comp B and gives IM responses ranging from Partial Detonation for Fast Cook-Off, Detonation for Slow Cook-Off, and Deflagration for Bullet Impact. The APKWS improved IM response involved changing the main explosive and explosive train and implementing a vent plug design. PBXW-114 was selected as the main charge with PBXN – 7 and PBXN – 5 as Booster and Lead materials respectively. The warhead case was modified with various venting plug designs to improve the fast and slow cook-off response. The plug design was developed to vent the out-gassed products of PBXW-114 and other energetic materials to be released from inside the warhead case and fuze body during a high temperature event, such as a shipboard fire. Venting of gas products is necessary to prevent pressure buildup in the warhead and fuze and subsequent detonation during a cook-off scenario. The design consists of a combination of unique mechanical shaped machined vent holes in which straight polymer plugs were press fit into the holes. The polymer used in the design will soften and will flow from the vent holes at temperatures around 275° F (135° C) allowing gas from heated out-gassing PBXW-114 and other energetic materials to be released. The placement and number of vent holes does not compromise the integrity of the wall-penetrating warhead and fuze case. The APKWS warhead loaded with PBXW – 114 with the vent plug design passed the Army fragment test where Comp B and PBXN – 110 had detonated.

1. Background:

The Army identified a requirement for a guided 2.75-inch rocket to complement the current unguided rockets, anti-tank missiles, and cannons of current and planned helicopters. The APKWS Block II Guided Rocket will increase stowed kills by providing precise engagement at standoff ranges with sufficient accuracy for a high single shot probability of hit against point targets. The APKWS Block II Guided Rocket will increase lethality through enhancements to the warhead and fuze.

Indian Head is teaming with General Dynamics on the warhead re-design effort for the APKWS system. Indian Head has been tasked with providing a warhead design that interfaces with the APKWS system and meets size envelope requirements. The main objective of the program is to improve the lethality against specified targets. The APKWS Block II Warhead and Fuze must also meet the requirements of MIL-STD-2105B.

Distribution Statement A: Unlimited – Approved for Public Release
Zachary A. Spears, NSWC - IH Divison, 101 Strauss Ave., Indian Head, MD 20640, (301)744-1930

2. Explosive Selection:

The explosive selection approach for APKWS was based on explosive characteristics related to safety, performance, and cost. In addition, only qualified explosives were considered for use in this system. Case venting of the Warhead and Fuze case would be used to reduce the violence of reaction in cook off. Once the explosives were selected limited IM evaluation of the APKWS warhead would be conducted. The MIL-STD-2105B testing would determine the response of the main charge in the APKWS warhead to Fast Cookoff (FCO) and Slow Cookoff (SCO) with and without venting, the response of the booster explosive to FCO and SCO in the APKWS fuze, and the response of the APKWS warhead (explosive and fuze) in cookoff environments.

2.1 Warhead Explosive Selection

The Statement of Work (SOW) implies a need for an explosive with good fragment driving and enhanced blast capabilities. Our approach for the explosive fill selection was to select the explosive material that would give the best warhead output to meet the needs for all target requirements. The potential fills were: PBXN – 110, PBXW – 112, PBXW – 128, PBWN – 9, PBXN – 10, PBXN – 111, PBXIH – 135, PBXN – 109, PBXW – 114, and PBXIH – 18. These potential fills are listed according to their enhanced performance characteristics for fragmentation (metal acceleration) or blast (thermobaric), and three candidate fills show enhanced performance in both blast and fragmentation. The following five performance-based criteria for fill selection were established:

1. Good fragment driving and enhanced blast (thermobaric) properties,
2. Good IM characteristics,
3. Evidence of survivability under penetration loading/setback,
4. Qualified explosive or low risk in obtaining qualification, and
5. Explosive Material and loading cost considerations.

PBXN-112 appears the optimum choice among the list of enhanced metal accelerating castable explosives. It has better fragment performance than the other castable explosives (PBXN-110 and PBXW-128). PBXN-9 is the best performer in metal acceleration alone, but is a more expensive fill due to the high HMX content and higher cost for pressed loadings. RDX based PBXN-10 is a less expensive fill, but it has marginally improved IM properties and is also a press loaded material. The blast/thermobaric explosives PBXN-111 and PBXIH-135 were comparatively poor fragmentation fills and, therefore, not an appropriate choice for optimum lethality against the target set. Of the explosives that perform well in both blast and fragmentation, PBXIH-18 was not qualified when the selection was made.

Based on these criteria, PBXW-114 as well as PBXN-112 and PBXN-109 were our leading candidates for explosive fill options. Table 1 shows the basic sensitivity indicators for PBXW – 114 and PBXN – 109. PBXW-114 has the best fragment driving performance of the two leading candidates. PBXW-114 has also demonstrated enhanced blast performance compared to PBXN-112 from testing in the open. Significant improvement by PBXW-114 over PBXN-110 has also been demonstrated in confined space testing similar to what would be encountered in a

Zachary A. Spears, NSWC - IH Divison, 101 Strauss Ave., Indian Head, MD 20640, (301)744-1930

SOW environment. Of the two leading candidates PBXW-114 has the best known IM characteristics as shown in Table 2. PBXW-114 also demonstrates better survivability than PBXN-112 in setback simulation testing; this implies improved reliability in a SOW target penetration environment. We will continue our evaluations but have three very good candidates that were producible, qualified, cost-effective, have desired performance, and can be readily integrated into test units.

Table 1. Basic Sensitivity Indicators

Characteristic	PBXW-114	PBXN-109
Impact Sensitivity	49 cm	25-52 cm
ESD 20/20 NF@	1.72 Joules	12.5 Joules
Friction Sensitivity	>980 Lbf	750 Lbf
LSGT	178 cards/27 Kbar, 22.0-24.5 Kbar	186-195 Cards/
TMD	1.72 g/cc	1.68 g/cc

Table 2. Results of tests in a Heavy Wall Penetrator (no fuze)

TEST	PBXW-114	PBXN-109
Fast Cook-off	Burn	Burn
Slow Cook-off	Burn	Burn
Bullet Impact	Burn	Burn
Fragment Impact	Deflagration	Explosion

NOTE- Average fragment velocity was 15% higher using PBXW-114 than achieved using PBXN-109

The performance of PBXN-110 in blast and fragmentation is nearly equivalent to the performance of 70/30 Octol, which is marginally better than Composition B in performance. Since PBXW-114 performs better than PBXN-110, it would be expected to have better fragment driving abilities than the current M151 explosive fill material.

2.2 Explosive Booster Selection:

Based on previous work done with the Mk 146 Mod 0 High Explosive Warhead, which was loaded with PBXN-110 for the main charge and PBXN-7 and PBXN-5 as Booster and Lead materials respectively, the APKWS team determined that these booster materials would work for them. In addition, because the fuze is located in a different position when compared to the Mk 146 and M 229 warheads, venting was used in the fuze area to permit energetic materials to be released during cook-off events.

2.3 APKWS IM Warhead and Booster Expected IM Response:

As discussed above in prior Fast & Slow Cook-off testing with PBXW-114 in the 5”/54 Caliber Projectile and in a heavy walled Naturally Fragmenting Warhead (NFW) with & without a PBXN-7 booster, the warhead has various results as shown in Table 3.

Zachary A. Spears, NSWC - IH Divison, 101 Strauss Ave., Indian Head, MD 20640, (301)744-1930

Table 3. Fast & Slow Cook-off testing with PBXW-114 with & without a PBXN-7 Booster

Test Results	5"/54 Projectile	NFW (Inert Booster)	NFW (PBXN-7)
Fast Cook-off	Burn	Burn	Deflagration*
Slow Cook-off	Explosion	Burn	Deflagration*

* Fuze expelled beyond 50 feet. The PBXW-114 explosive burned, and unburned explosive found in the case.

The above results demonstrate that with pressure relief, the PBXW-114 main charge will simply burn and with pressure relief, similar results are expected for the PBXN-7 booster.

3. Vent Plug Design:

The purpose of the vent plugs is to release pressure build up that occurs if a catastrophic event happens in which the warheads will be heated above normal environmental conditions. Different designs were considered. These designs looked at different geometrical possibilities as well as vent plug material selection. The final design is a press fit plug that is secured in the warhead via barbs. See Figures 1 and 2.

Insensitive munitions testing will be conducted on this design. These tests will include both fast and slow cookoff. There will be two configurations for each test one with eight vent plugs and one with sixteen vent plugs. Figure 1 shows the configuration of the vent plugs for the eight-plug design. The sixteen-plug design will add an additional set of plugs offset and rotated from the ones in the eight-plug design.

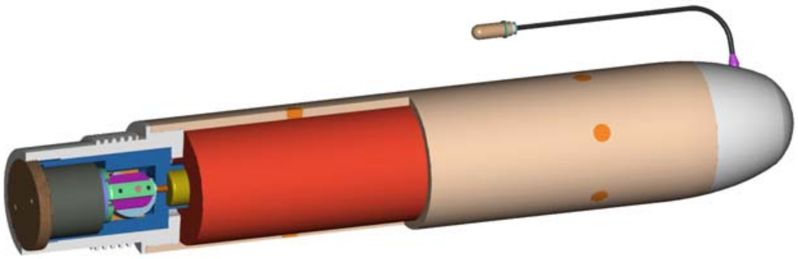

Figure 1. Warhead with vent plugs shown.

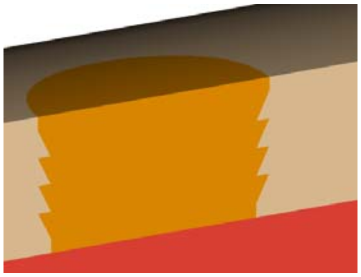

Figure 2. Close up of vent plug geometry.

Zachary A. Spears, NSWC - IH Divison, 101 Strauss Ave., Indian Head, MD 20640, (301)744-1930

The vent plugs are made of high-density polyethylene (HDPE). The geometry of the vent plugs is shown in Figure 3.

Figure 3. Vent plug final geometry.

3.1 Preliminary Vent Plug Testing

Prior to cookoff testing this design underwent successful preliminary testing. The preliminary testing hardware consisted of a steel simulated warhead case. The novel plug design shape shown was successfully machined into the case. High-density polyethylene plastic plugs were machined and inserted using a shop press. The warhead cases were pressure tested at various temperatures, to simulate storage and slow cook-off. The plugs did not leak and held over 1000 PSI internal pressure at normal operating and storage temperatures of –40 °F, ambient, and 160 °F. At a temperature of 275 °F, the material softened and was expelled with less than 25 PSI internal pressure.[2]

4.0 Bullet Impact Test

For the 50 caliber bullet impact testing a warhead with the 16 vent plugs configuration was used. See Figure 4.

Figure 4. 2.75” Warhead ready for bullet impact testing.

The bullet type is a M2 AP .50 caliber. The impact velocity was within the MIL-STD-2105B specs and was a direct hit on warhead. It resulted in a slow deflagration reaction with continuous burning till explosive was spent. Results are summarized in Figures 5, and 6.

Zachary A. Spears, NSWC - IH Divison, 101 Strauss Ave., Indian Head, MD 20640, (301)744-1930

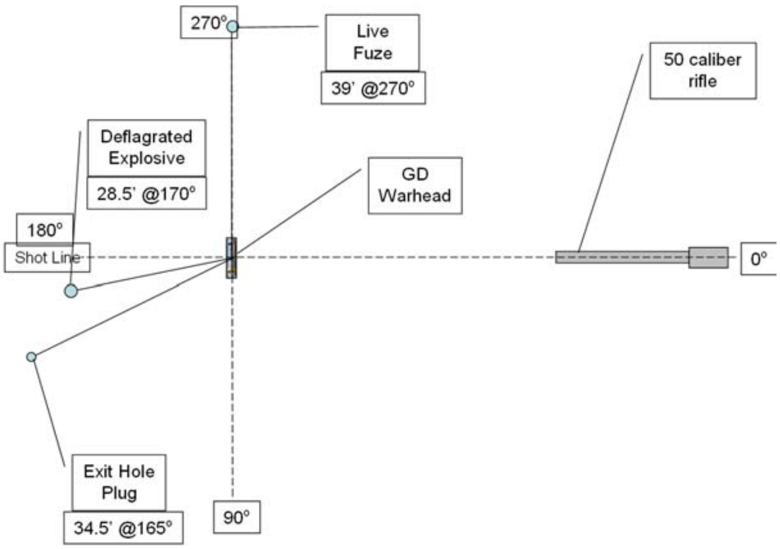

Figure 5. Fragment positions.

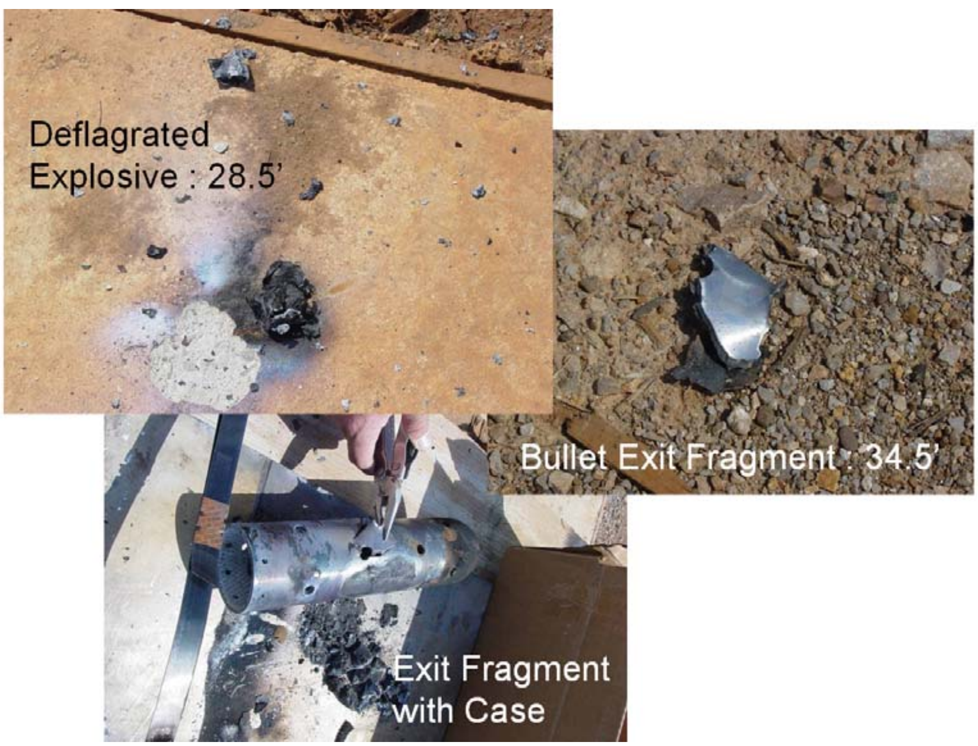

Figure 6. Post test pictures.

5.0 Army Fragment Impact Testing

For the fragment impact testing a round with 16 vent plugs was used. It was placed on foam 5.625 inches away from a 4 foot x 1 foot x 1 inch thick aluminum witness panel. A 40 mm cannon was used to fire a 18.17 gram pre-formed fragment with a four piece sabot with a mass of 92.83 grams. 350 grams of 50 BMG powder was used to propel the fragment assembly. The impact point was 6 inches from the warhead nose. The fragment velocity was measured at 6043 feet per second using time of arrival gages (located as shown in Figure 8). 1.80 of 2.3 pounds of the explosive billet was recovered unreacted. The warhead case ruptured from the force of the fragment impact. The witness panel received no damage or deformation from reaction. A 226.7 gram steel fragment was recovered approximately 120 feet away. Pressure gages were used to determine violence of reaction and the measured pressure was minimal. See Figures 7 through 9 for visual summary.

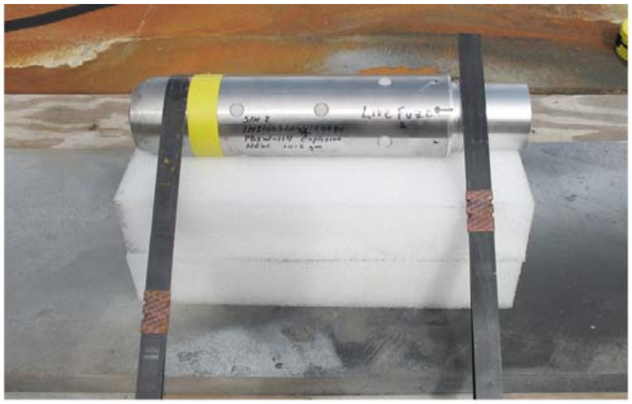

Figure 7. Orientation of warhead on left. Fragment assembly on right.

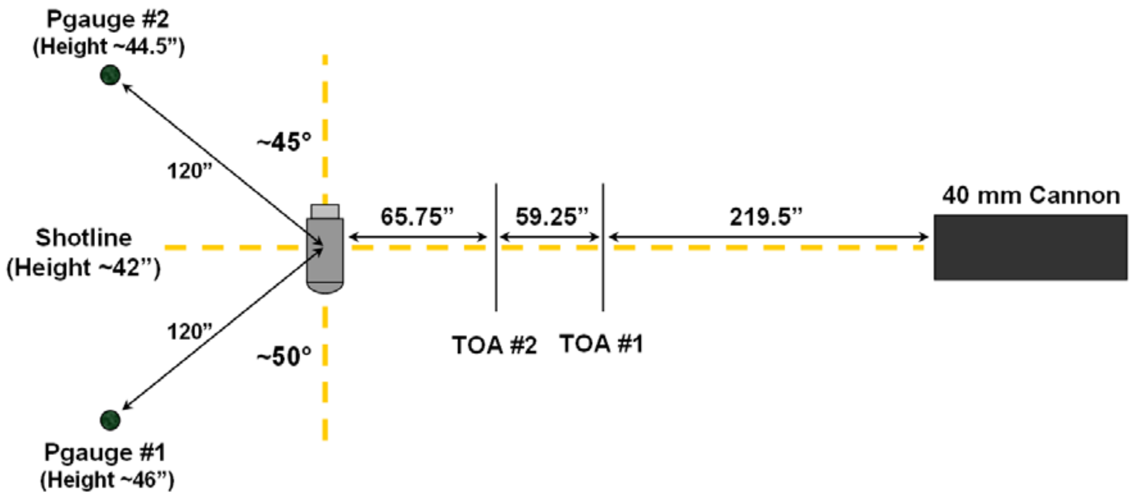

Figure 8. Test setup diagram.

Zachary A. Spears, NSWC - IH Divison, 101 Strauss Ave., Indian Head, MD 20640, (301)744-1930

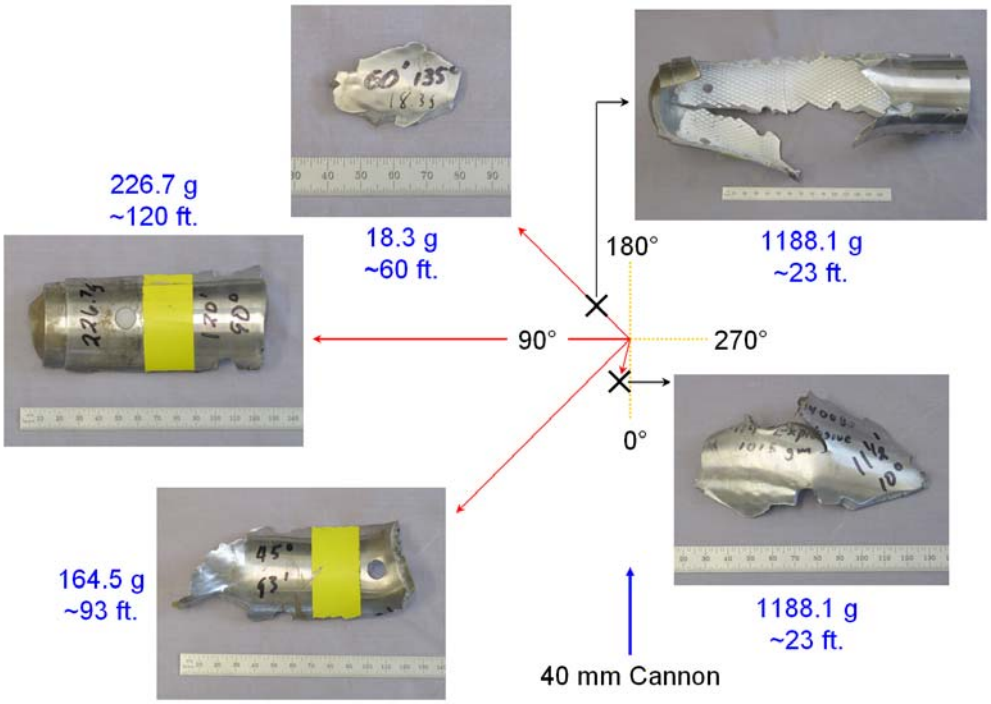

Figure 9. Post-test recovery.

6.0 Fast Cookoff

The FCO response for the warhead configured with the fuze and booster will be conducted in accordance with MIL-STD-2105B. This test has not yet been completed.

7.0 Slow Cookoff

The SCO response for the warhead configured with the fuze and booster will be conducted in accordance with MIL-STD-2105B. This test has not yet been completed.

8.0 Acknowledgements

Kevin Gessner, IHD/NSWC APKWS Project Manager. IHMD/NSWC for their support in warhead design and development and for their help during performance testing during the development of the APKWS Warhead. General Dynamics, Ordnance and Tactical Systems for their support throughout this program.

9.0 References

1. APKWS drawings dtd May 2004
2. NSWC Indian Head Division Internal Report of 11 Oct 04 by Z. Spears and M. Sanford, *APKWS – Insensitive Munitions Vent Plug Design.*

Zachary A. Spears, NSWC - IH Divison, 101 Strauss Ave., Indian Head, MD 20640, (301)744-1930