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Shaped Charge Initiation Test Configuration for IM Threat Testing

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Rocket propelled grenade (RPG) shaped charge attack threats are of particular concern for Insensitive Munitions (IM) development. In response to these threats, the U.S. Project Engineering Office for Ammunition (PEO Ammo) have worked with the U.S. Army Armament Research, Development and Engineering Center (ARDEC) Energetics and Warheads Division (EWD) to develop a highly reproducible and well characterized standardized 81mm shaped charge jet initiation test configuration. This 81mm shaped charge and jet attack configuration is used to determine whether an acceptable explosion or lower level response is observed. The test is completed as per STANAG 4526. The 81mm shaped charge is comprised of a high precision forged and machined liner made from C101 Oxygen Free Copper (OFE, UNS C10100) and a bare billet LX-14 pressed billet configuration that is machined to final dimensions. This warhead choice overcomes the issue of testing variability observed if actual production RPGs are used for Insensitive Munitions (IM) threat testing. The test configuration includes an aluminum buffer plate that is used to condition the jet for desired jet characteristics, as well as a representation for RPG probe position. Modeling and simulation was used to develop the shaped charge and test configuration. The resulting configuration has been experimentally characterized using flash radiography for short and long stand-off in order to provide quantified jet characterization including velocity profiles, accumulated length, accumulated mass, jet diameter and v2d profiles. The result is a simple reproducible test configuration that represents an RPG attack geometry. The test configuration has been adopted by the U.S. DoD for RPG IM threat testing and has been used on a large variety of munition test articles.

INTRODUCTION

Rocket Propelled Grenades (RPG) are widely available and used throughout the world [1]. A large variety of grenades are made in many different countries. RPG grenades have become one of the most dominate threats, particularly in urban terrain. A variety of grenades are available with basic RPG shaped charge grenades being a dominantly used. Figure 1 presents photographs of confiscated RPG grenade launchers and grenades. The RPG shaped charge threat is of particular concern for Insensitive Munitions (IM) development. For this reason, the PEO Ammo has worked with the ARDEC EWD to develop a standardized representative IM threat testing shaped charge configuration with highly reproducible jet characteristics.

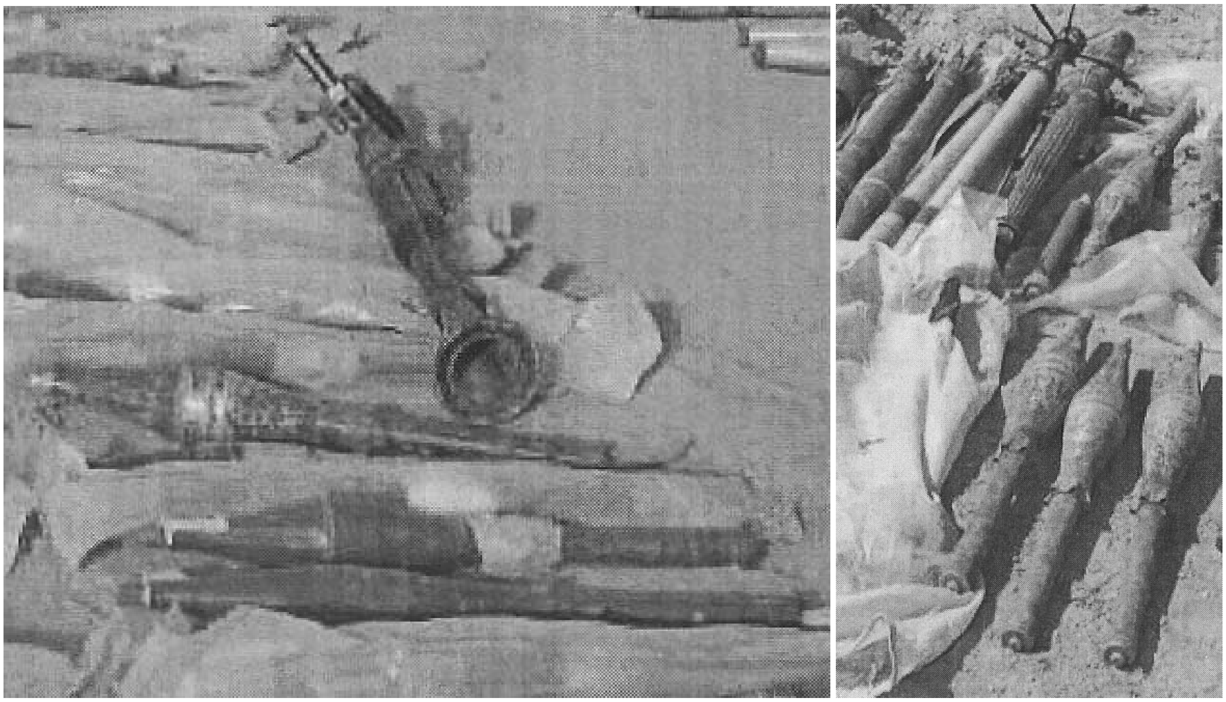

Figure 1. Confiscated RPG grenade launchers and grenades.

TEST CONFIGURATION DEVELOPMENT

Modeling and simulation was used to develop the IM RPG threat shaped charge and test configuration. The CALE [2] arbitrary Lagrange-Eulerian high rate continuum model was used extensively. The high rate continuum modeling was conducted to accurately identify the jet mass characteristics. As many RPG grenades have been observed to perform erratically, this characterization provides a sound basis for achieving consistent testing configurations that clearly represent RPG shaped charge grenades characteristics. Based on basic RPG grenades, a standardized shaped charge initiation test configuration was developed as a generic RPG representative configuration for IM threat testing. This warhead test configuration choice overcomes the issue of testing variability observed if actual production RPGs are used for IM threat testing. Figure 2 shows representative modeling of RPG shaped charges. It is noted from the modeling the RPG nose cone probe produces considerable jet interaction and is known to consume high velocity jet as a result. A very simple test configuration representative of RPG shaped charge threats was developed by ARDEC, and is shown in figure 3. This RPG threat testing configuration is based on the very well characterized 81mm shaped charge [3]. It was designed to be somewhat geometrically similar to common RPG rounds although it is built with high precision and quality materials and methods in order to provide consistent performance. The geometry consists of a standard LX-14 loaded 81mm shaped charge with no wave shaper. A relatively thick (4”) aluminum stripper plate, known as the “buffer plate”, is placed in front of the liner at a fairly short standoff. The aluminum buffer plate is required to strip away some of the high velocity jet, similar to the nose cone and probe on common RPGs. The front of the aluminum plate is situated to represent the correct positioning of an RPG nose cone. The resulting jet characteristics are extremely similar to those produced by common RPG shaped charges.

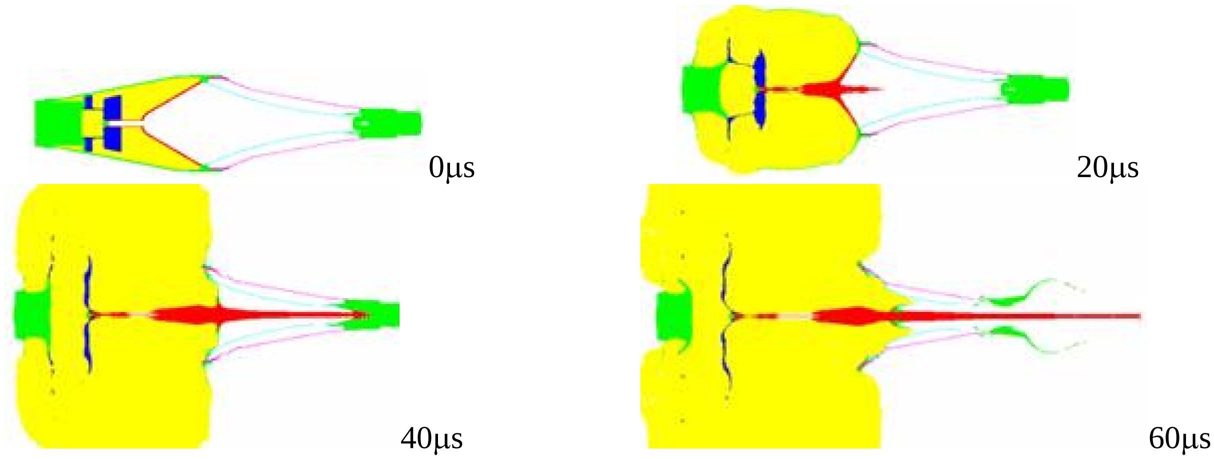

Figure 2. CALE modeling material plots of RPG shaped charge jet formation.

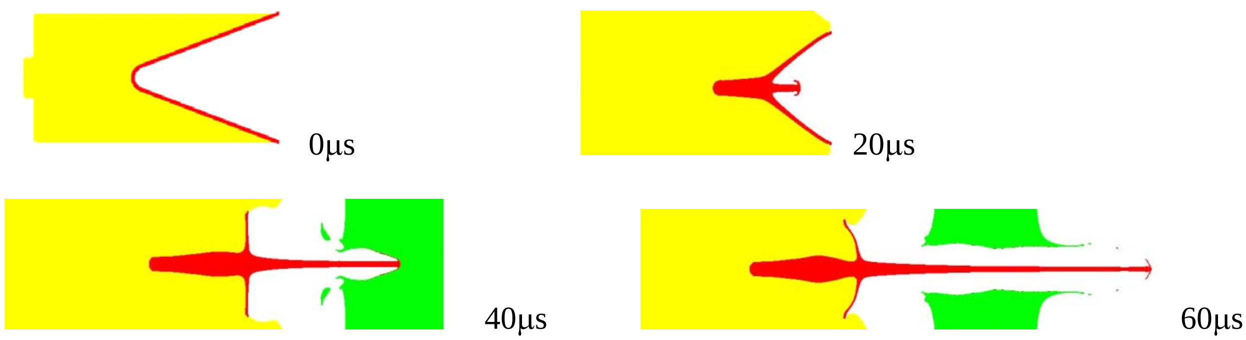

Figure 2. CALE modeling used for RPG IM threat test development based on a standard LX-14 loaded 81mm shaped charge.

EXPERIMENTAL CHARACTERIZATION

Figure 4 presents the resulting RPG IM threat test configuration and LX-14 81mm shaped charge warhead. The 81mm shaped charge is comprised of a high precision forged and machined liner made from C101 Oxygen Free Copper (OFE, UNS C10100) and a bare billet LX-14 pressed billet configuration that is machined to final dimensions. Figure 5 presents a drawing of the 81mm shaped charge copper liner. Experimental characterization of the LX-14 81mm shaped charge included jet characterization using long standoff x-rays. The x-rays were taken up to a 24 charge diameter standoff in order to assure jet characterization for the fully particulated jet. Figure 6 presents the resulting shaped charge jet x-rays. A jet tip velocity of 6.2 Km/s was measured, which agrees with modeling results. The jet characteristics were reduced using a digitizing light table and ARDEC developed software. Figure 7 presents the shaped charge characterization jet length vs. jet velocity for the fully particulated jet. Figure 8 presents the shaped charge characterization jet diameter vs. jet velocity for the fully particulated jet. The presented jet diameter is measured as the largest diameter of each jet particle. Figure 9 presents the shaped charge jet characterization jet break-up time vs. jet velocity. The break-up time is calculated using the particulated jet length velocity profile and the known standoff from the original warhead position. The results are relatively consistent and indicative of a high precision shaped charge built using a high quality liner made from relatively pure copper.

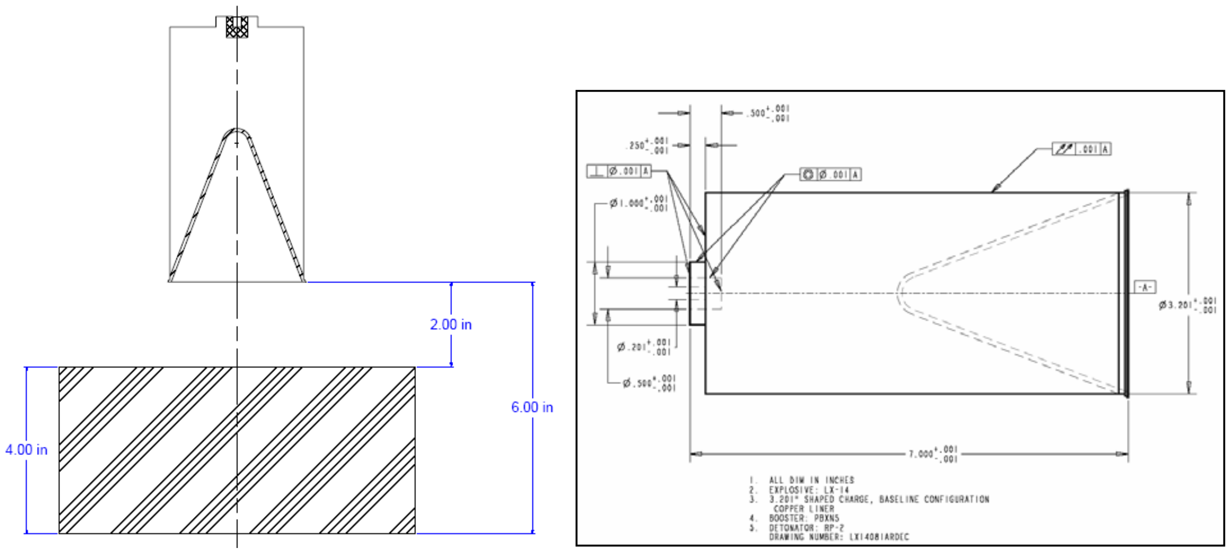

Figure 4. IM RPG threat test configuration (left) and warhead (right).

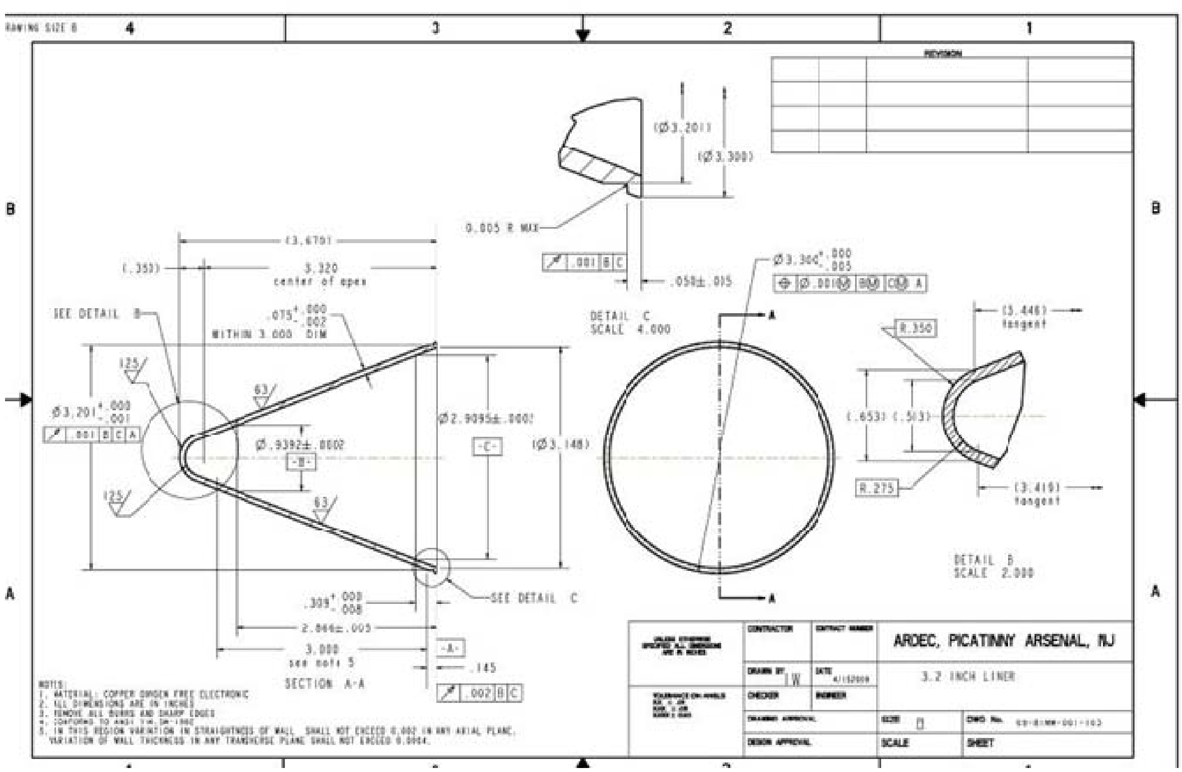

Figure 5. Liner drawing

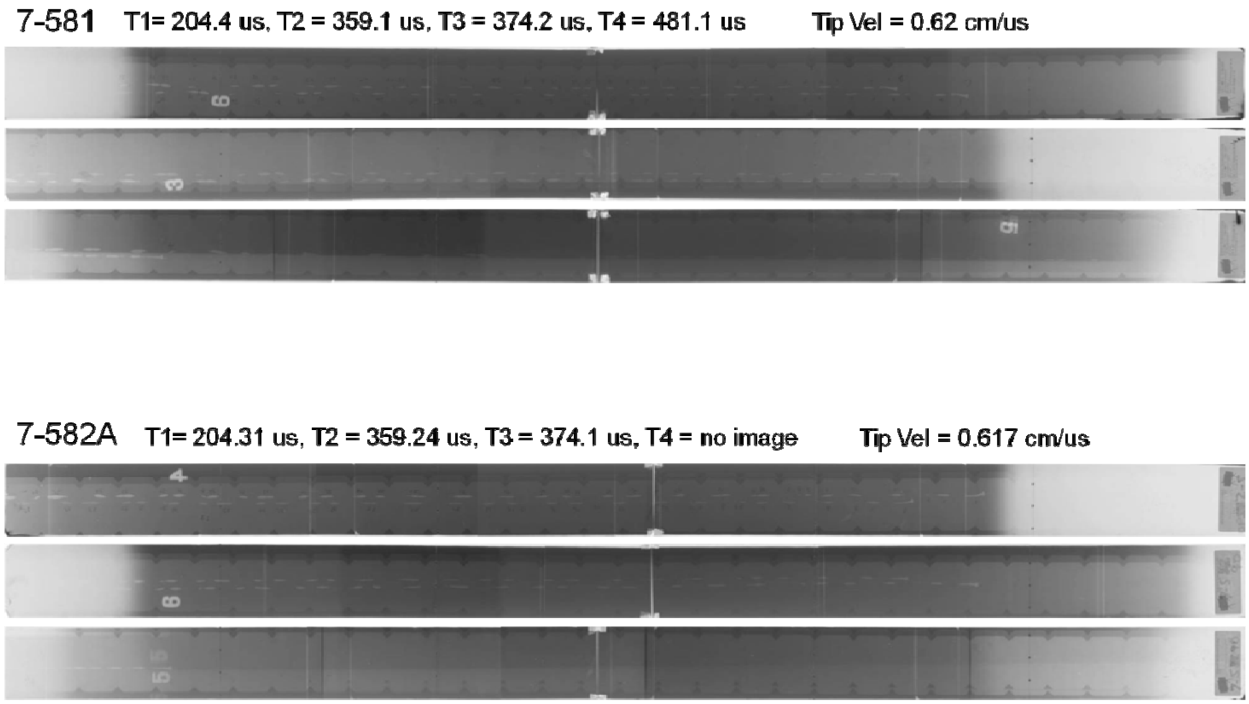

Figure 6. Shaped charge jet characterization long standoff x-rays.

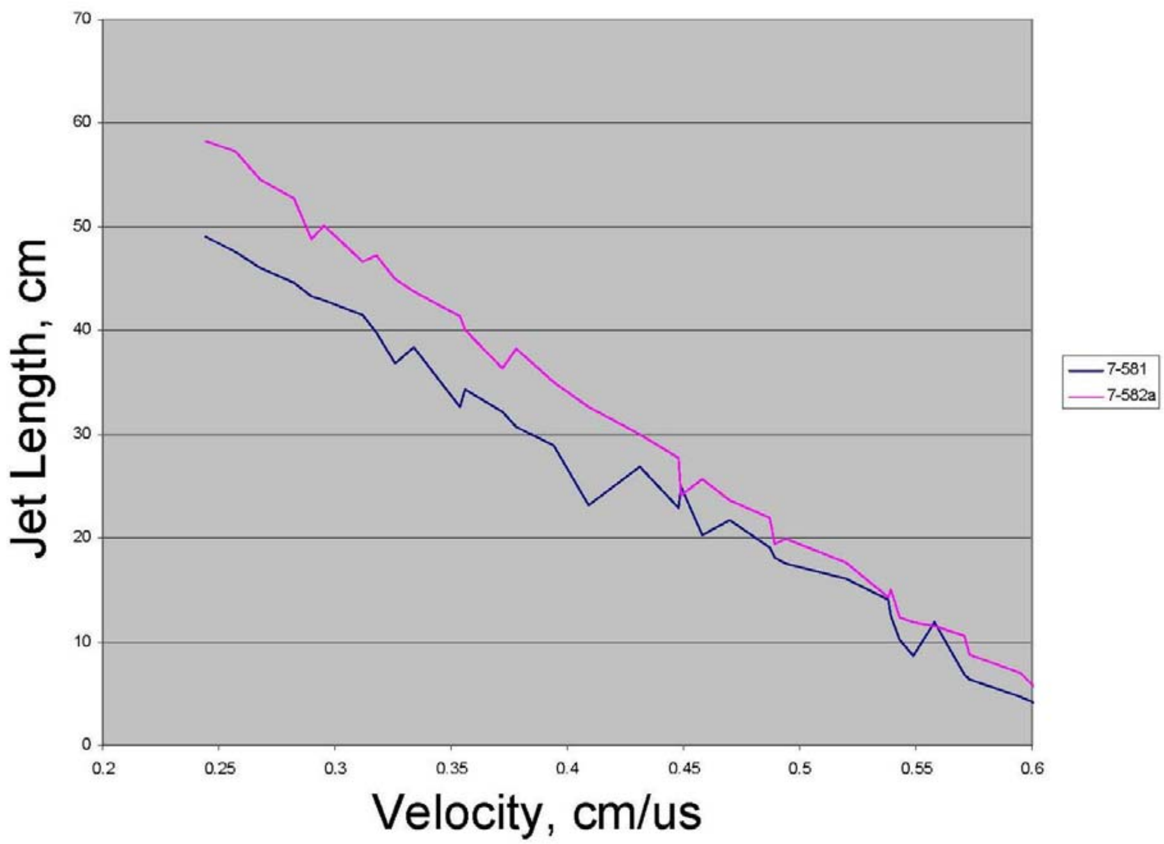

Figure 7. Shaped charge characterization jet length vs. jet velocity.

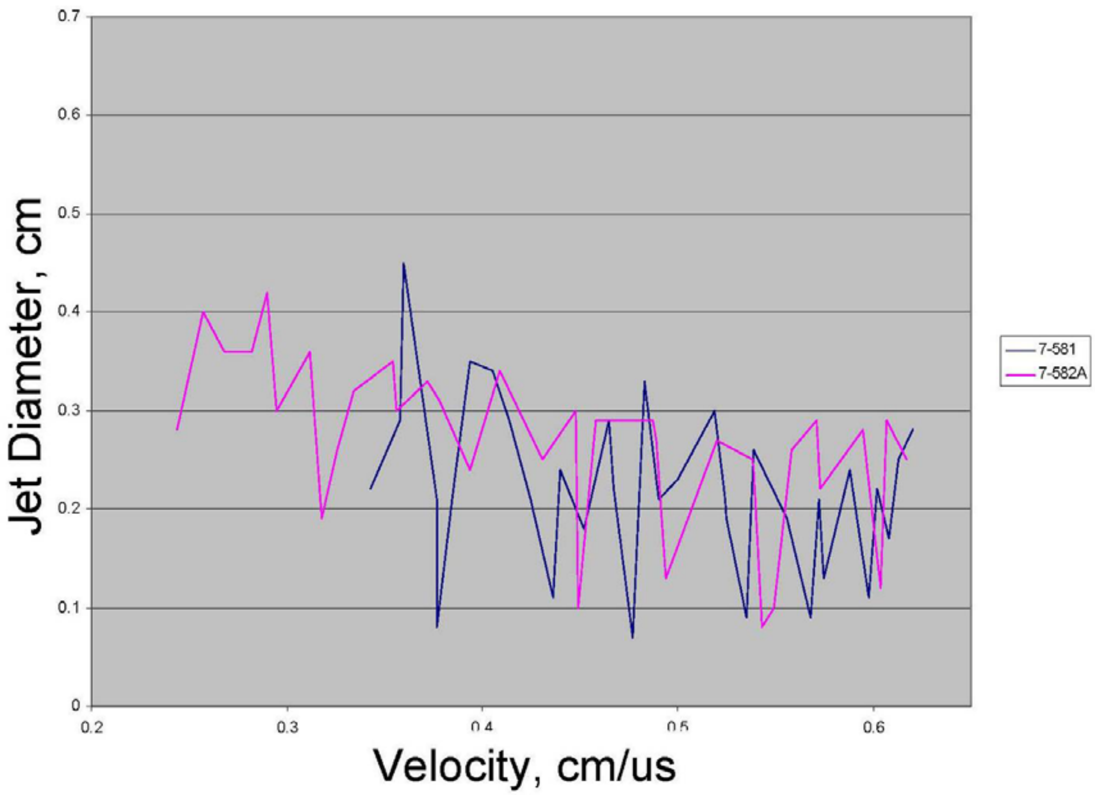

Figure 8. Shaped charge characterization jet diameter vs. jet velocity.

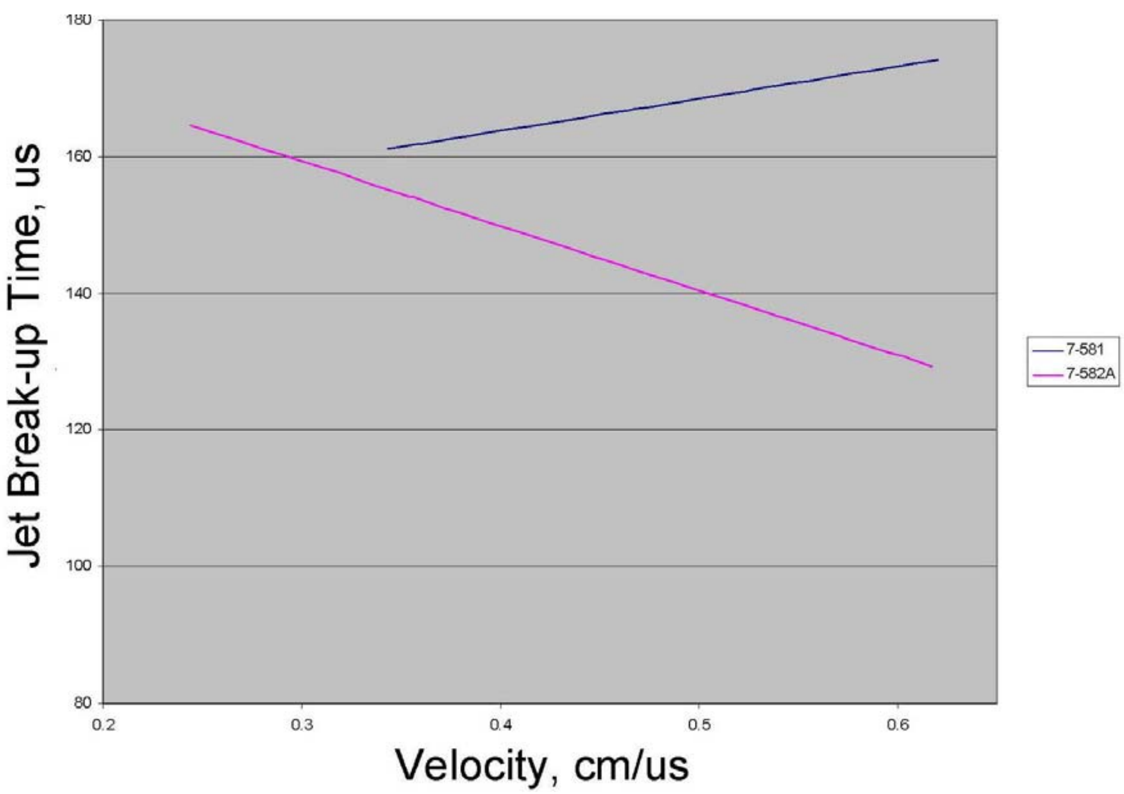

Figure 9. Shaped charge jet characterization jet break-up time vs. jet velocity.

TEST CONFIGURATION SPECIFICS

The shaped charge IM threat test is completed as per STANAG 4526. The RPG IM threat test configuration has been developed so the back of the Al buffer plate represents the probe nose position of the RPG. As shown in figure 10, the back of the Al buffer plate is placed in the geometric position to represent the RPG attack probe nose position. To facilitate testing, a set of standardized test configuration hardware has been developed as shown in figures 11, 12, 13, 14, 15 and 16. Although this hardware is not required to achieve the standardized RPG threat testing configuration, it can greatly facilitate the testing. Figure 11 provides photographs of the LX-14 loaded 81mm shaped charge and the shaped charge in the test assembly configuration. As shown in figures 12, 13, 14 and 15, the standardized configuration hardware is based around an acrylic holder. The acrylic holder that is made by clamping two acrylic triangles together. The acrylic triangles corners are drilled and tapped in order to provide threaded holes for clamping using threaded rods. The space between the triangles is adjusted to allow for the 4” aluminum cylinder and 2” air gap positioning, as well as to ensure that components are level and aligned. For testing, an approximate ½” of standoff clearance is left between aluminum cylinder face and the target test article. If the standardized test configuration hardware is being used in the vertical position, than the threaded leveling rods (3) from figure 12 are used to ensure proper alignment. If the standardized test configuration hardware is being used in the horizontal position, than the threaded leveling rods (4) from figure 12 are used to ensure proper alignment. If the aluminum spall produced by the shaped charge jet Al buffer plate perforation is of concern, a stripper plate can be used to prevent the Al spall from impacting the test article, as well as to achieve the 1/2" gap between the Al buffer plate and the target test article. A stripper plate design and assemble configuration is shown in figures 12 and 16.

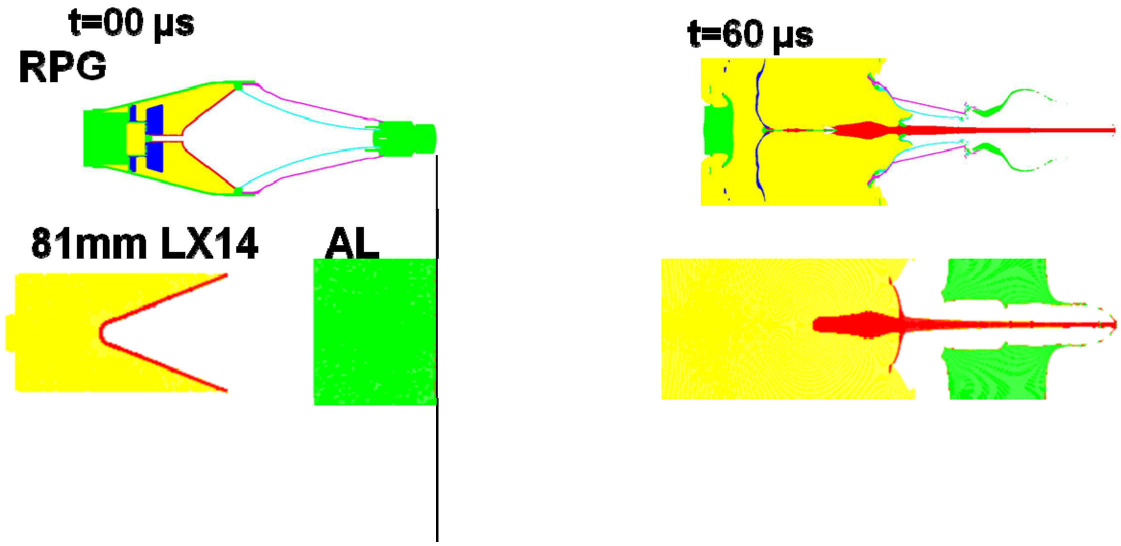

Figure 10. The back of the Al buffer plate represents probe nose position of the RPG. For IM threat testing, place the back of the Al buffer plate in the geometric position to represent RPG attack probe nose position.

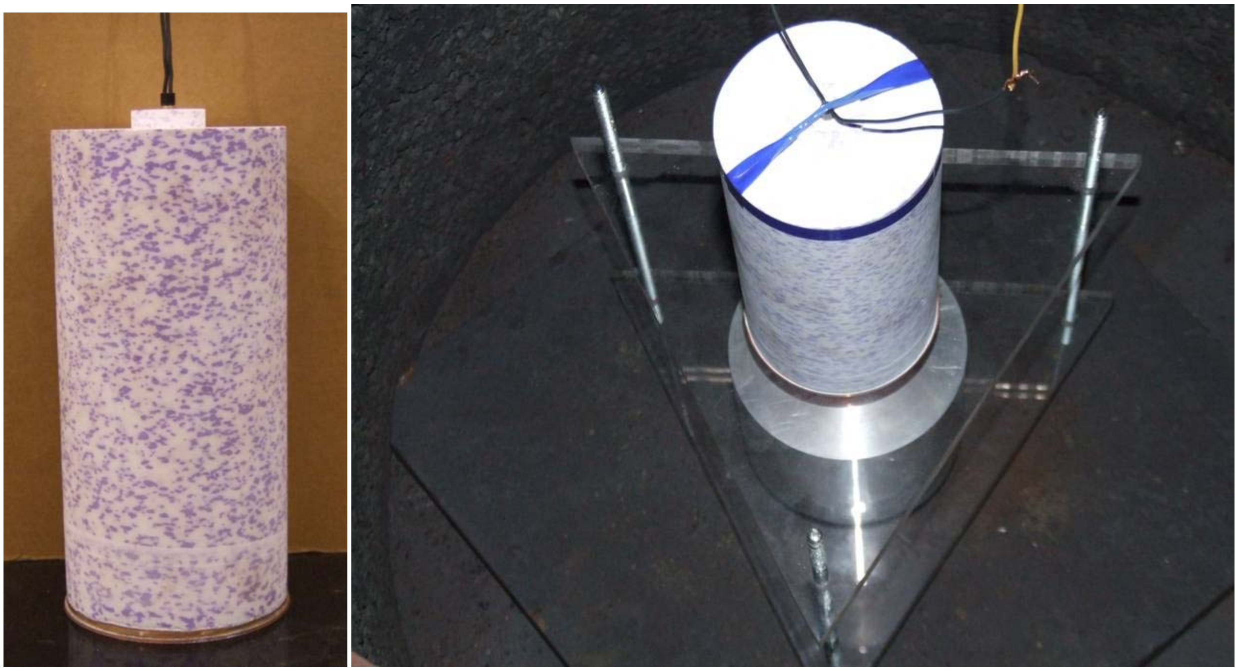

Figure 11. Shaped charge (left) is typically assembled into a test configuration using a set of standardized hardware.

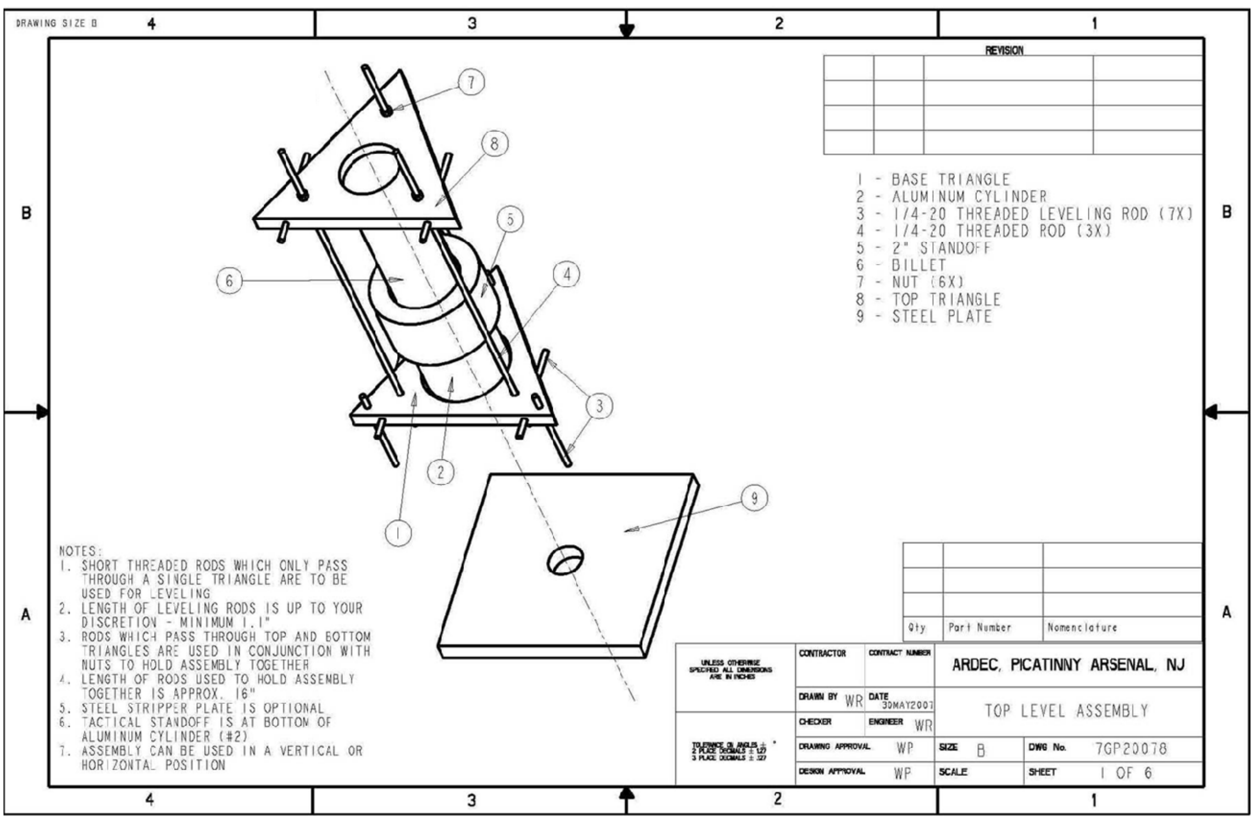

Figure 12. Standardized test assembly and hardware.

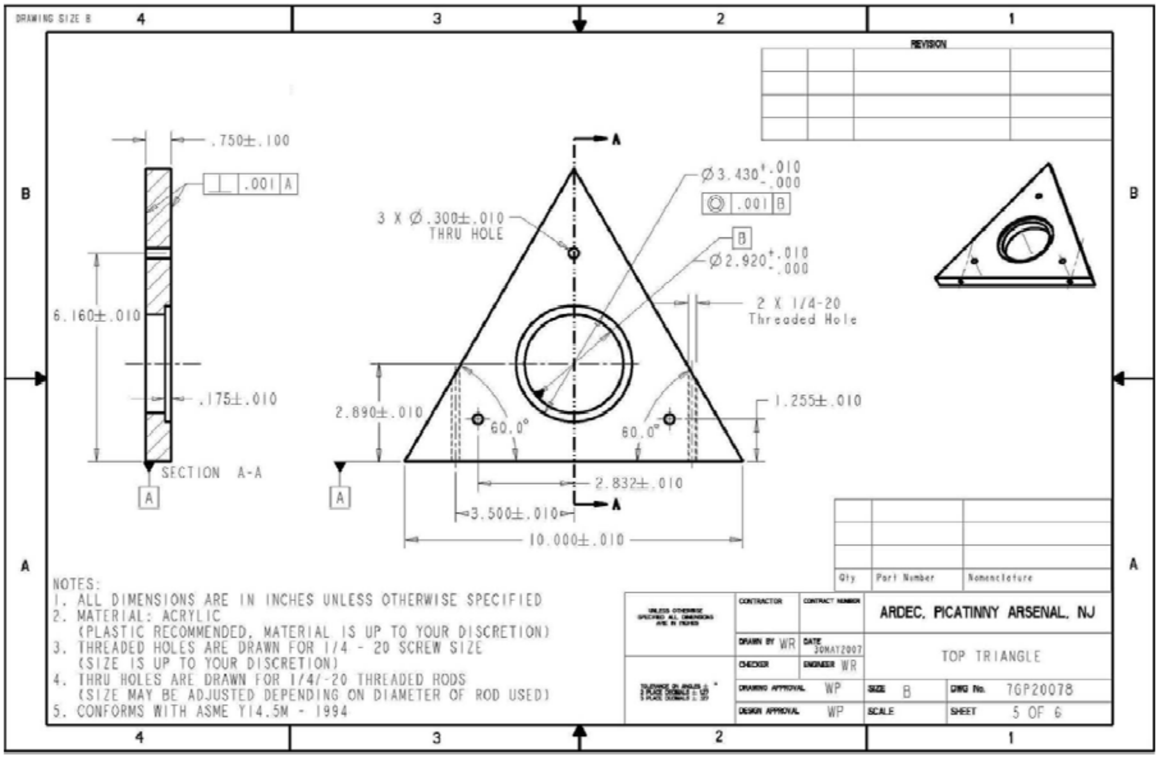

Figure 12. Assembly hardware drawing.

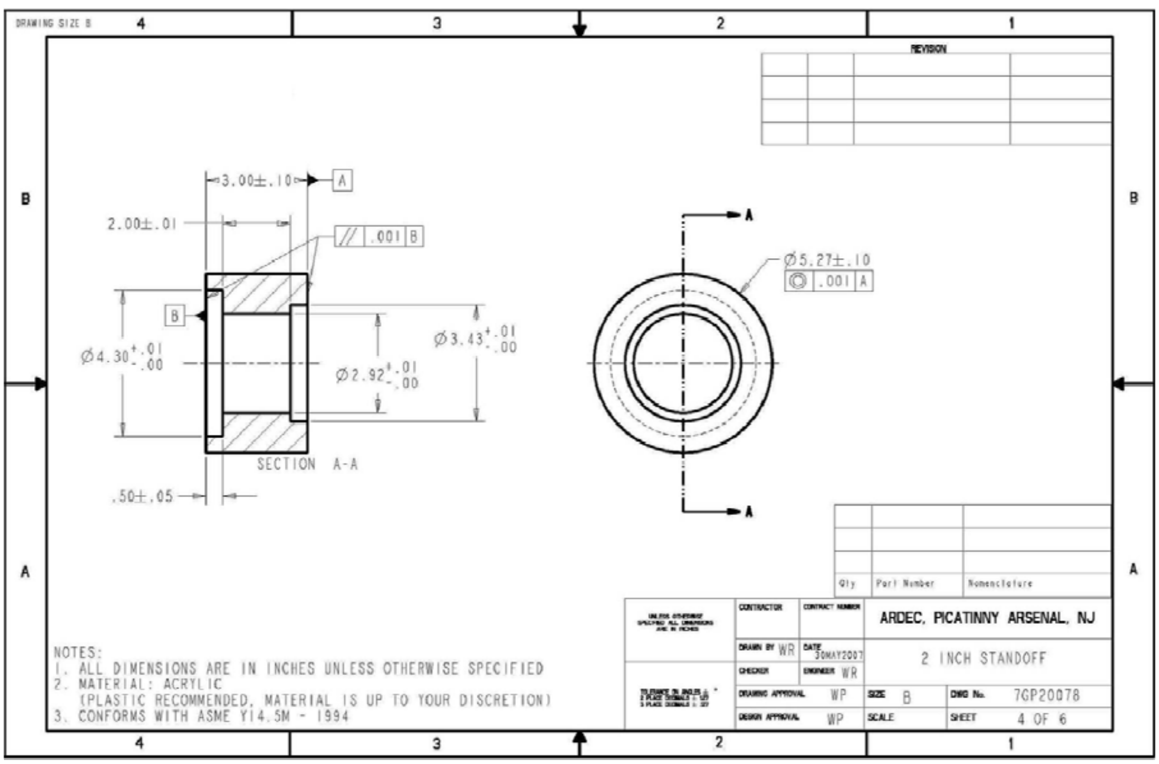

Figure 13. Assembly hardware drawing.

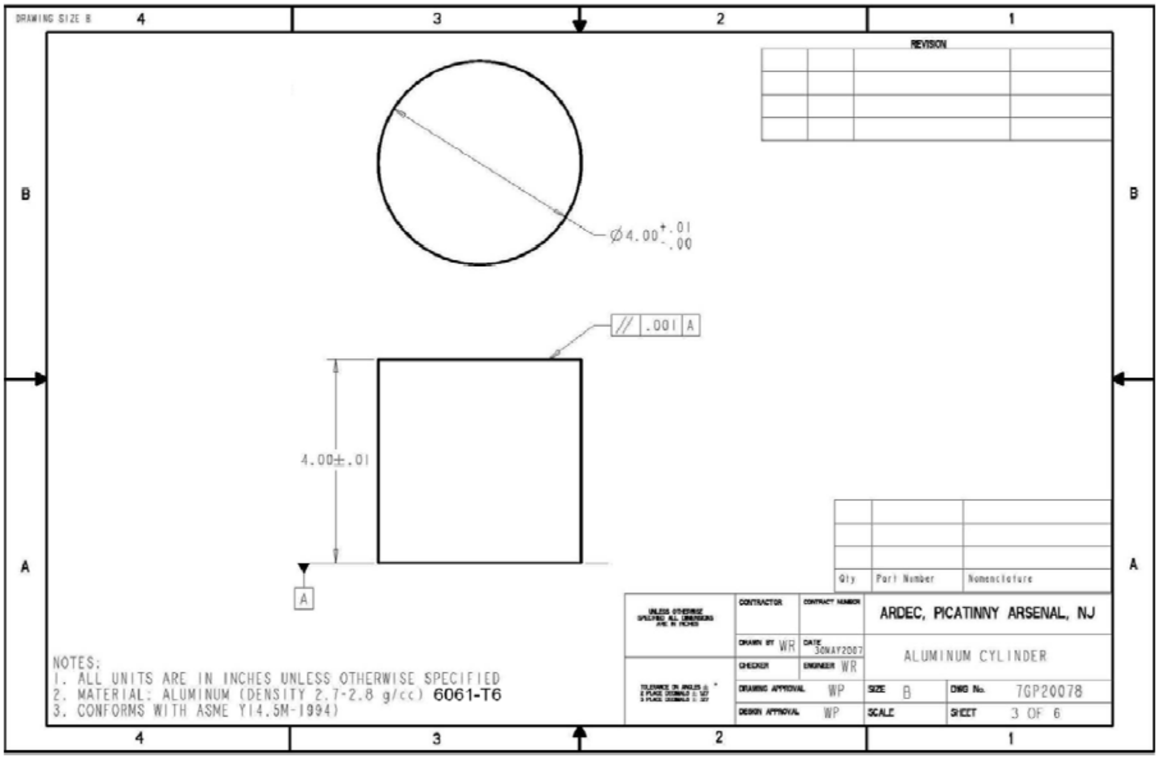

Figure 14. Aluminum buffer plate drawing.

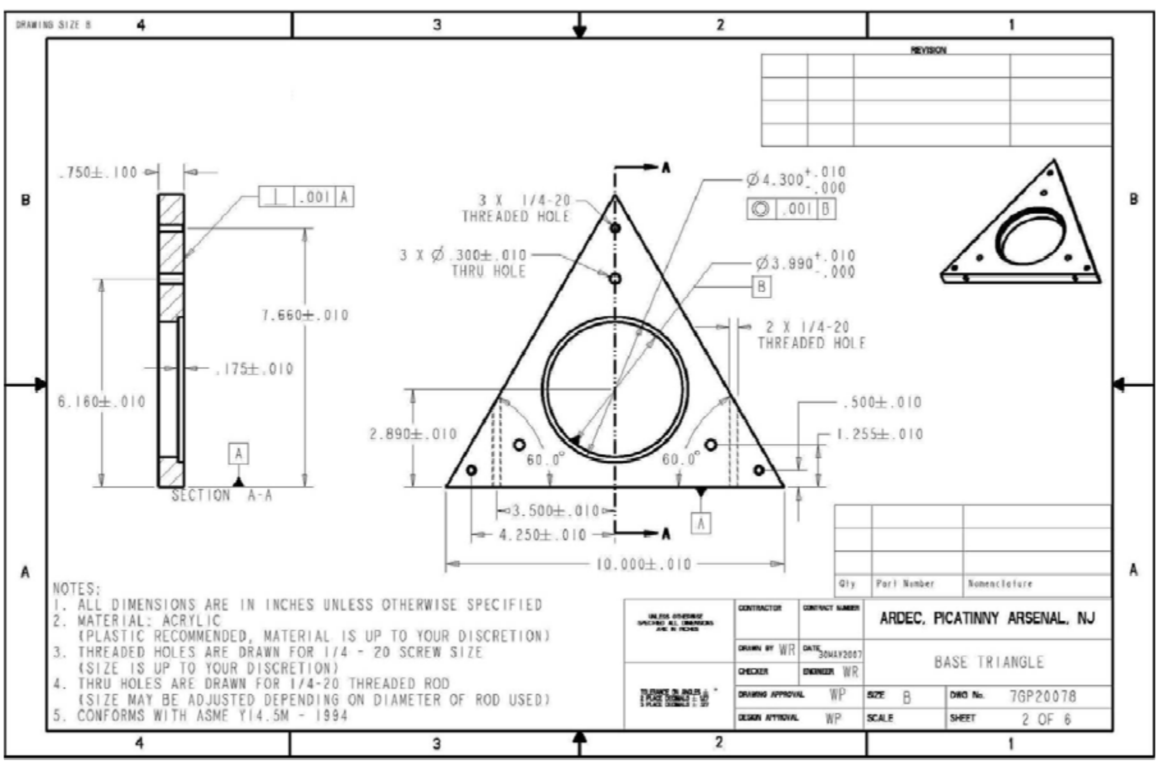

Figure 15. Assembly hardware drawing.

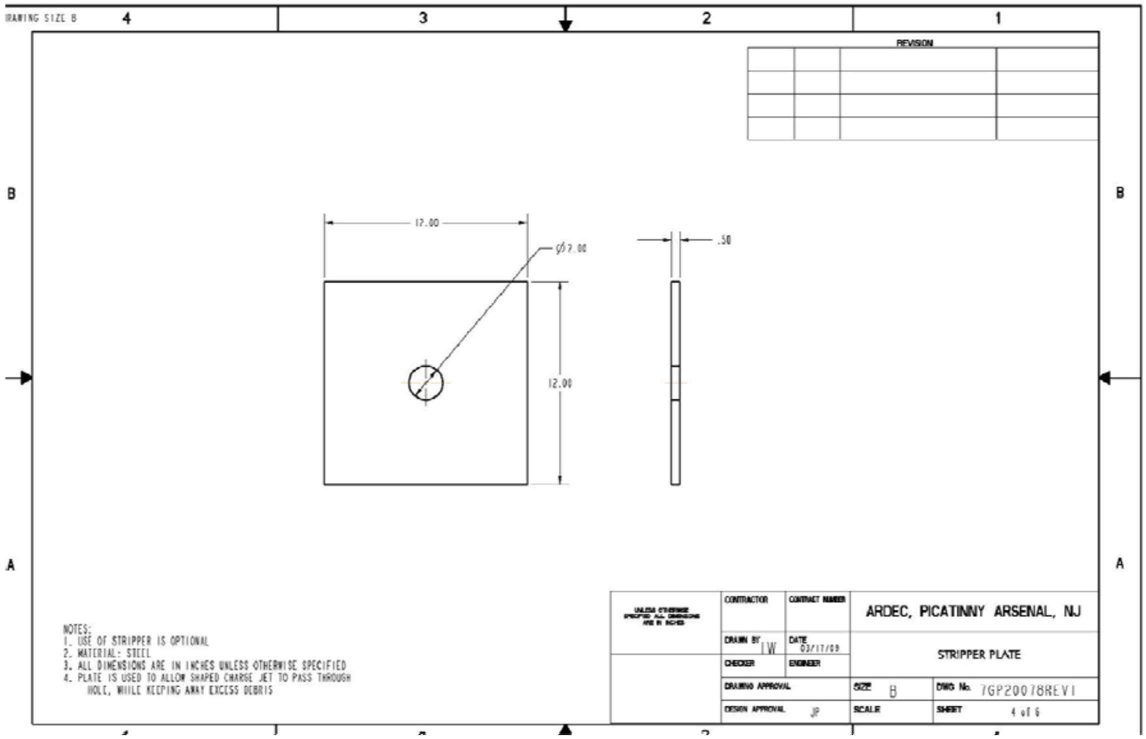

Figure 16. Stripper plate hardware drawing.

SUMMARY

The U.S. Army PEO Ammo and the ARDEC EWD have collaboratively developed a highly reproducible and well characterized standardized 81mm shaped charge jet initiation test configuration that is representative of RPG IM threats. This 81mm shaped charge and jet attack configuration is used to determine whether an acceptable explosion or lower level response is observed. The test is completed as per STANAG 4526. This warhead choice overcomes the issue of testing variability observed if actual production RPGs are used for IM threat testing. The test configuration includes an aluminum buffer plate that is used to condition the jet for desired jet characteristics, as well as a representation for RPG probe position. Modeling and simulation was used to develop the shaped charge and test configuration. The resulting configuration has been experimentally characterized using flash radiography for short and long stand-off in order to provide quantified jet characterization including velocity profiles, accumulated length, accumulated mass, jet diameter and v2d profiles. The result is a simple reproducible test configuration that represents an RPG attack geometry. The test configuration has been adopted by the U.S. DoD for RPG IM threat testing and has been used on a large variety of munition test articles.

REFERENCES

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2. R. Tipton, *Cale Users Manual*, Lawrence Livermore National Laboratory (January 1997).

3. A.J. Schwartz and E.L. Baker, "Effect of Interior Surface Finish on the Break-up of Copper Shaped Charge Liners", Proceedings of the 18th International Symposium on Ballistics, San Antonio, TX College Park, MD 15-19 November 1999.