EXPERIMENTAL VALIDATION OF RAVEN: A NEW SPECIES OF GUN FOR THE OBJECTIVE FORCE

Eric L. Kathe*, Michael J. Glennon, and Richard W. Tortorici
U.S. Army, TACOM-ARDEC Benét Laboratories and
Andrew J. Kertis Jr. and Norman J. Stam
ARES, Inc., Port Clinton, OH

ABSTRACT

RArefaction waVE guN (RAVEN) propulsion is an enabling technology to provide future war fighters with lightweight guns that impose less recoil burden and provide improved thermal management. This will allow the war fighter to engage with maximum firepower and to keep firing longer. First conceived by the first author in March 1999 as part of the Army After Next (AAN) project, RAVEN has recently been experimentally validated by a test gun firing NATO standard Oerlikon 35mm TP ammunition. There exist no known physics barriers to prevent successful development of RAVEN. Broad applications for RAVEN include system integration of platform and gun combinations as diverse as: a 16 ton Future Combat System (FCS) ground vehicle firing a 120mm gun, a HMMWV or M113 firing a 105mm howitzer, the shoulder of an objective force warrior (OFW) firing a 14.5-25mm rifle, or an unmanned combat aerial vehicle (UCAV) firing a 75mm cannon.

1. CHALLENGES THAT RAVEN OVERCOMES

Potential FCS armament options include large caliber guns, tactical missiles, electromagnetic railguns, and directed energy weapons. Of these, only gun and missile technology appear mature enough for serious near-term FCS consideration for most targets to be engaged. Both have demonstrated overwhelming lethality.

There exist three principal disadvantages to an orthodox gun. First, gun recoil imposes substantial shock severity upon the platform to which it is mounted. Second, guns get hot as they fire. Third, guns are heavy.

For these reasons, questions have been raised regarding the deployablity of FCS's that integrate big guns (Ogorkiewicz, 2002). In particular; can a big gun such as a 120mm tank cannon be integrated within a future fighting vehicle that is strategically deployable by means of a C-130 Hercules transport? Can a howitzer be deployable that can provide sustained fire?

Compact and rugged gun ammunition affords a logistically appealing FCS armament solution that is of great advantage for sustainability. However, missiles are most amenable to lightweight fighting vehicle integration that is critical to FCS deployablity.

1.1 Why Guns Remain Heavy Into The 21st Century

Guns remain heavy, despite advances in material technology, for two principal reasons. Their thermal mass is required to manage the heat generated during burst-fire. Also, the inertia of heavy guns aids in recoil –lighter guns are endowed with more recoil energy during firing than heavier guns. Therefore, RAVEN propulsion technology, with a proven ability to reduce gun recoil and barrel heating, may be anticipated to enable existing lightweight materials technology for guns. This enabling technology may therefore provide the sustainability of a gun based armament solution while meeting the deployability and lethality requirements of the objective force.

2. THE RAVEN PRINCIPLE

If the breech of the chamber of a gun is suddenly vented (opened) while the projectile is being propelled down the bore, a delay time will occur before the pressure loss at the chamber can be communicated forward to the base of the projectile.

Prior to venting, RAVEN functions as an orthodox gun. Subsequent to venting, the gun operates much like a recoilless rifle, venting the hot propellant gases through an expansion nozzle integrated at the breech. This nozzle cools and depressurizes the gases as they are accelerated to high rearward velocities. Their internal heat energy is converted into the kinetic energy of the resulting jet that generates forward thrust at the nozzle.

For howitzer ammunition, such as a zone 6, 155mm shot, it has been shown that venting when the projectile has traversed less than 35% of its travel down a 59 caliber gun will not slow it down. For a 120mm M829A2, the venting may occur just before the projectile has traversed 25% of its travel down an M256 bore and will jettison approximately two thirds of the propellant gas through the nozzle. These remain astonishing results (Kathe, 2000).

2.1 The Trick

RAVEN's counterintuitive propulsion is enabled by the limiting speed that the loss in pressure at the breech of the gun may traverse the bore towards the muzzle. This gas dynamic phenomenon is termed a ***rarefaction wave*** in compressible flow jargon and it travels through the bore at the same speed that a sound wave would. (Rarefaction is synonymous with "*thinning of gases*" as pressure is lost.) When the delayed venting is timed such that the rarefaction wave chases the projectile down the bore and just meets the base of the projectile as it exits the muzzle, the timing is considered synchronized. Venting that occurs at this time or later will not degrade projectile propulsion relative to an equivalent gun that does not vent the chamber. In essence, if the projectile does not "*hear*" the venting, its muzzle velocity will not be affected nor will its ballistic efficiency be impaired.

2.2 Cool Cannon

RAVEN dramatically reduces barrel heating as the hot erosive propellant gases are removed from behind the projectile —before the projectile has exited the muzzle.

2.3 Quiet Cannon

Perhaps not quiet, but the report of a synchronized RAVEN should compare favorably to that of an orthodox gun. A high level of *lingering* thermal energy remains in the propellant gases of an orthodox gun as the projectile exits the muzzle. This energy becomes manifest as muzzle blast, and to a lesser extent, additional barrel heating (particularly towards the muzzle).

RAVEN leverages this *lingering* energy to accelerate the gases rearward through a nozzle, generating forward thrust. This reduces the latent thermal energy of the gas discharge leaving less energy to generate signature while reducing the chances of flash. (The inefficiency of prior recoilless rifles caused them to release more than five times as much signature energy as their orthodox counterparts —explaining their raucous reputation.)

3. EXPERIMENTAL VALIDATION

RAVEN was verified by firing thirty standard 35mm Oerlikon TP rounds down a modified gun. Vent timing was achieved by engineering a straight blowback bolt. The bolt was propelled rearward within an extended chamber by the same propellant gases that were concurrently propelling the projectile down the bore. Unlike historical blowback guns (such as the M3A1 0.45 caliber "grease gun") the cartridge case was modified by means of a notch to intentionally rupture the head from the body. When the bolt traversed a sufficient distance, the back of the gun was "uncorked." Timing was governed by the mass of the bolt and the distance traversed to uncork the gun.

Conceptually, this is depicted in Fig. 1, shortly after commencement of the venting. (Alternative venting methods are also being investigated.)

3.1 58% Less Recoil And 40% Less Heat Transfer

The results of this testing demonstrated a 58% reduction in recoil momentum and a 40% reduction in barrel heating relative to an equivalent gun that did not vent. There was no loss in muzzle velocity (Kathe, 2002). The ruptured body of the cartridge case was often ejected from the chamber late in the reversed blow-down, while the head always fell away after blow-down.

Because of the transient nature of RAVEN, the gas pressure and temperature at the breech of the chamber just after venting declined dramatically within 200μs. Inspection of an unprotected steel nozzle vent with twenty shots on it showed no evidence of erosion. There was simply too little time for damage to occur.

4. CONCLUSIONS

RArefaction waVE guN (RAVEN) propulsion is an enabling technology to provide future war fighters with lightweight guns that impose less recoil burden and provide improved thermal management. This will allow the war fighter to engage with maximum firepower and to keep firing longer.

5. REFERENCES

Ogorkiewicz, R. M., "Heavy Weapons for Light Vehicles," Jane's International Defense Review, May 2002, pp. 38-42.

Kathe, E. et al, "Rarefaction Wave Gun Propulsion," Proceedings of the 22nd Army Science Conference, 11-13 December 2000, Baltimore, MD, pp. 222-229.

Kathe, E., "Rarefaction Wave Gun Propulsion," Ph.D. Thesis, Rensselaer Polytechnic Institute, Troy, NY, May 2002.

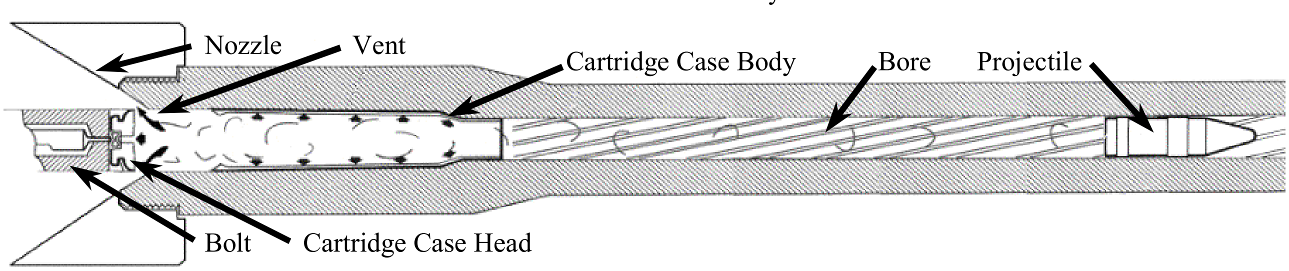

Figure 1: Schematic of a blowback bolt-operated RAVEN shortly after commencement of the venting.