Electrothermal-Chemical (ETC) Technology Weaponization Issues

Brad Goodell
United Defense, L.P.
Armament Systems Division
4800 East River Rd.
Minneapolis, MN 55421

brad.goodell@udlp.com

ELECTROTHERMAL-CHEMICAL (ETC) TECHNOLOGY WEAPONIZATION ISSUES

In order for ETC technology to be weaponized, serious consideration must be given to address critical issues in the areas of: propellants, pulse power, plasma devices, power connection, fire control, munitions interface/integrated round, and system integration. This paper provides an overview of these critical issues.

1.0 INTRODUCTION

Electrothermal-chemical (ETC) gun technology is an advanced gun propulsion concept that utilizes both chemical and electrical energy to provide increased performance within the constraints of existing conventional gun and bullet technologies.

Electrothermal-chemical gun propulsion technology utilizes electrical energy in the form of a high-temperature, high-energy plasma to augment and control the release of chemical energy stored in propellants in order to achieve significant performance enhancements over existing conventional guns. The propellants being used are existing solids and developmental solids. The performance enhancing benefits provided by an ETC gun system for direct and/or indirect fire applications are:

- Improved accuracy/hit probability with precise ignition timing
- Maximum performance at all temperature conditions with temperature compensation
- Increased lethality and range with higher muzzle velocities
- Soft launch of acceleration-sensitive munitions
- Hypervelocity potential

A schematic of a generic ETC gun is shown in Figure 1. The three major subsystems are (1) the pulse power system, consisting of energy storage devices such as batteries or flywheels; power conditioning devices such as converters, alternator rectifiers, or pulsed alternators; and power compression devices such as capacitive-based pulse forming networks (PFNs), or pulsed alternators; (2) the ammunition, which includes the launch package, propellant and the plasma generator; and (3) the cannon, inclusive of gun barrel, breech, and power connection.

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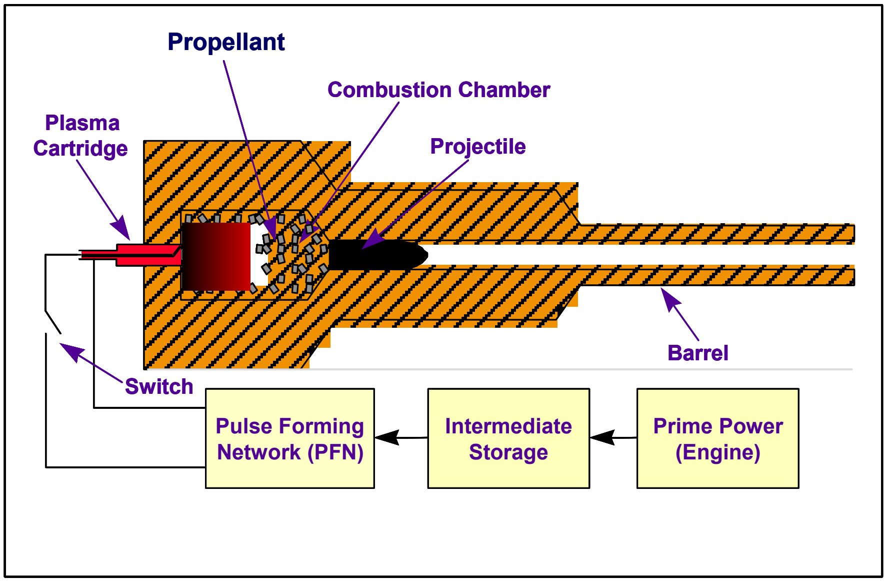

Figure 1. Schematic ETC Gun

2.0 WEAPONIZATION ISSUES

ETC technology has been under development since the mid-1980's. In recent years, significant performance gains have been realized. Actual test date has been extremely promising, but little thought has gone into addressing critical ETC technology issues. In order for ETC technology to be weaponized, serious consideration must be given to address critical issues in the areas of propellants, pulse power, plasma devices, power connection, fire control, munitions interface/integrated round, and system integration.

3.0 PROPELLANTS

ETC propellants (Figure 2) must provide the performance necessary to meet requirements. Significant increases in propellant energy density and loading density are an absolute must. As new propellants are being developed, it is important to understand the plasma/propellant interaction. Traditionally, propellants have been developed that are ignited by chemistry. With the use of plasmas for ignition, it is important to understand the impact of the "color of plasma" on the propellant. It is conceivable that a whole new form of energetics could be developed that is insensitive to most forms of ignition, yet respond to just the proper "color of plasma".

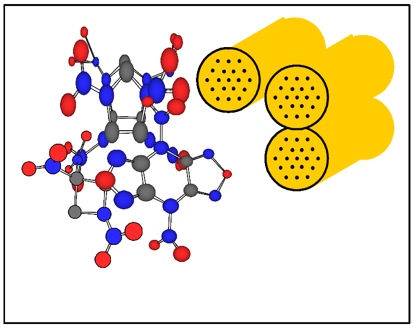

Figure 2. ETC Propellants

The development of ETC propellants should address similar issues facing the development of conventional propellants. Consideration should be given to temperature extremes, performance at those temperatures, safety in handling (shock, vibration, drop tests), shelf life, processing techniques, producibility, cost, environment, insensitive munitions, no residue, as well as a host of other issues.

Inherent in the development of the propellant, serious consideration of the potential of a plasma device fault is needed. Based on years of experience, we believe that a plasma device fault results in "base" ignition of the propellant bed, and therefore the configuration of the propelling charge must be amenable to base ignition. Base ignition must be considered even in the case where the length of the propelling charge is quite long.

4.0 PULSE POWER

ETC pulse power systems and components, as shown in Figure 3, face a myriad of issues. Critical issues are component energy density (mass and volume), efficiency, fault tolerance, reliability, durability, and magnetic field containment. The design of the pulse power system architecture is fundamentally driven by propellant characteristics and the type of plasma device used in the system. Also critical to pulse power system design are thermal issues associated with numbers of rounds and firing rate. Time at voltage for "silent watch" operation must also be considered.

Figure 3. Pulse Power

Specifically, looking at pulse power components, consider the following: high energy density/power density of batteries in a military environment; capacitor efficiency, capacitor energy density (J/g and J/cc); capacitor survivability; capacitor life/allowable voltage reversal; field-free inductor development; cost, architecture development and definition for ETC loads, and possible other types of loads; fault mode isolation; safety; shock load survivability; RAM; EMI; human interface; all-weather operation; signature management; high action/high rep-rate switching; optimal voltage; optimal power profile; and robust power conditioning.

It has been our observation that pulse power development for ETC has lagged the development of the actual technology for years. We believe that it is time to invest in pulse power system development, or ETC technology will not be ready for fielding in the next several years.

5.0 PLASMA DEVICES

Plasma devices come in a variety of designs, as shown in Figure 4. Critical to weaponization, consider the following: coaxial nature of the device to minimize the effect of stray E and B fields; optimal plasma arc length (either confined or not); manufacturability; ability to undergo a manufacturing pre-test; chemical backup (if propellant allows, nice to be able to fight hurt, or in degraded mode); design for safe round operation during fault; high reliability; possible use in currently fielded munitions; any leave behinds (either in stub case or full case); and impact of fault on the cannon.

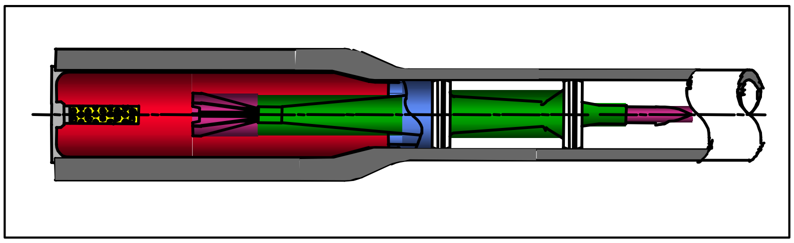

Figure 4. Plasma Devices

We have had limited experience with “re-useable” plasma devices, and would suggest that the development of such a device at the energy and power levels of interest would be very challenging. We believe these problems could not be resolved in the foreseeable future.

6.0 POWER CONNECTION

Weaponization of the power connection faces many issues as well. We believe that the following issues need to be addressed:

- Power connection should be coaxial in nature; must be reliable, available and maintainable
- Should consider allowing the firing of conventional munitions (interface with conventional primers)
- Should minimize the number of electrical contacts; the need to manage electrical contact force and magnetic forces
- Current return path must be controlled

- Management of thermal loads
- Management of electrical contact stroke distances (will be different depending on caliber and gun system)
- Consider electrical contact compliance; cleanliness of contacts; and material selection
- Avoid magnetization of gun components
- Simple on-board replacement

7.0 FIRE CONTROL

Fire control systems will be upgraded to include impacts of precision ignition, temperature compensation, and interface to the pulse power system. We believe that a combination of precision ignition and precision aim techniques could significantly improve direct fire accuracy.

In considering next generation fire control systems for ETC weapons, one may need to consider the impact of novel recoil mitigation techniques, as well as the impact new light weight cannons/gun mounts. As is always the case, understanding of cannon/gun dynamics is needed in order to better develop fire control. In order to maximize the effectiveness of the gains offered by temperature compensation, reasonably accurate round temperatures will need to be known. With today's technology, we are also able to know the propellant lot characteristics of each individual round, thus adding even more effectiveness to next generation gun systems.

8.0 MUNITIONS INTERFACE/ INTEGRATED ROUND

Up until now, this paper has addressed ETC component issues, but in the development of the technology, clear focus on the ultimate objectives should be given. This includes the development of an integrated round (an example is shown in Figure 5). Fundamentally, the integrated round must consider impact of plasmas on round components. Consideration should be given to of the interface with a variety of munitions. One must demonstrate: no fin damage (if fins are indeed present); no damage to tracers; interface understanding with combustible, consumable; metallic; or non-metallic case materials. Understanding the potential for higher spin rates at higher muzzle velocities for spin-stabilized rounds, and subsequent increase loading on rifling is needed. One should consider the impact of higher g-loads on fuses, guidance/navigation and control systems, as well as any warhead systems/subsystems. Higher g-loads are not a direct outcome of ETC technology, but rather higher operating pressures that are possible with new cannon materials resulting in the consideration of designing for higher g-loads on munitions. ETC technology has demonstrated soft-launch capability with g-sensitive munitions. We have shown equivalent muzzle velocity at 35 percent lower pressure with ETC guns.

Figure 5. Integrated Round

Finally, as one considers the integrated round, ease of LAP is very important.

9.0 SYSTEM INTEGRATION

In our opinion, the development of ETC technology must continue with a focus on system integration. Fundamentally, one should ask the question, what are the targets of interest, how should we service the targets, then define defeat mechanisms, and then “fly” this defeat mechanism back to the launcher. It is only now that one can begin to define the requirements of the armament system, and ultimately the integrated vehicle (Figure 6).

Figure 6. Integrated Vehicle

Once the requirements are known and understood, some of the system integration issues that should be considered are: location of pulse power, ease of maintenance, human safety, implications of increased power through slip rings, type of prime power, turret balancing, impact of design requirements on stabilization system; ammunition resupply ,and other such typical system issues.

10.0 CONCLUSION

This paper has outlined and discussed important weaponization issues affecting the continued development of ETC technology. ETC weapon systems will someday be a reality, but not before these critical issues are addressed and systematically solved through the standard rigorous engineering process.