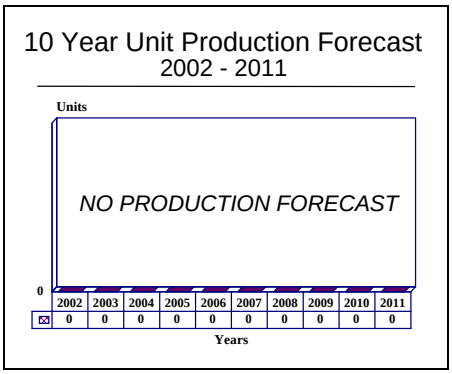
Electrothermal (ET) Gun - Archived 3/2003

Outlook

- Electrothermal and electrothermal-chemical guns are interesting technologies without convincing naval applications
- Navy side of project de-emphasized to Army side in the mid-1990s
- Existing and future land-attack requirements met by 5-inch Mark 45 L62 and 155 millimeter AGS
- Missiles preferred option for anti-missile system



Orientation

Description. A range of new-technology naval guns intended to provide point defense for US warships and fire support for US troops undertaking amphibious operations.

Sponsor

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Contractors

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Licensee. No licenses have been granted.

Status. Inactive; observation continues of relevant technologies for possible future applications.

Total Produced. Only bench units for RDT&E work have been developed.

Application. Guns using this technology are intended for future installation on US frigates, destroyers and amphibious warfare ships, to provide anti-missile point defenses, as well as short/medium-range land attack and support capability.

Price Range. No pricing information is available.

Technical Data

Characteristics

Muzzle Velocity	1.2 - 1.4 km/sec
Bore Size	60 mm
Firing Rate	4 rounds/sec
Burst Size	10 rounds

Projectile	Guided
Ammunition	Conventional or Electrothermal
Elevation	+30/-5 degrees
Train	+/-45 degrees

Propelling Charge Munition Performance

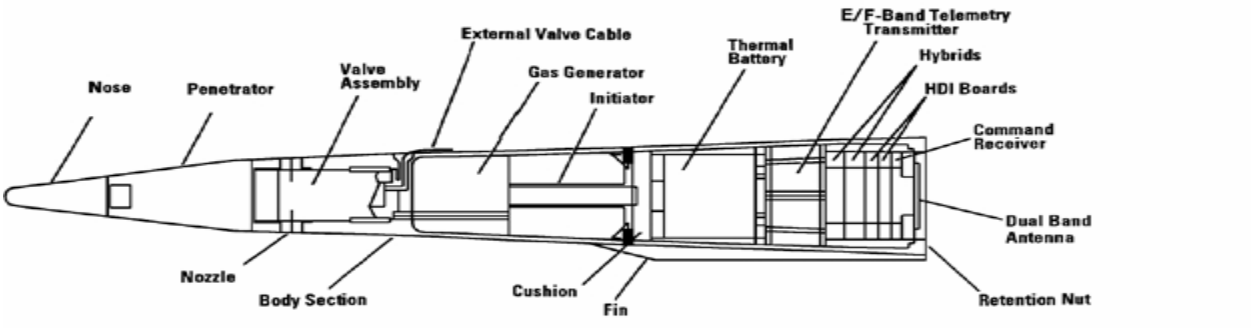
Gun Bore	60 mm
Projectile Mass	2.5 - 3.5 kg
Muzzle Velocity	1.2 - 1.4 km/sec (min)
Muzzle Energy	2.5 MJ (min)
Velocity Variation	1%
Acceleration	30,000 - 40,000 g
Chamber Pressure	70,000 psi (max)
Electrical Energy Input	1.5 to 2 MJ

Design Features. The family of electrothermal guns uses combustion-augmented plasma (CAP) technology, a high-energy gun technology announced by FMC in 1987. This type of gun is a hybrid between an electrothermal (ET) and a liquid-propellant (LP) cannon; about 20 percent of muzzle energy is derived from an electrically generated plasma, and 80 percent from a conventional chemical reaction as in other liquid propellant guns. Compared to a pure electromagnetic gun, the CAP gun requires about a third as much electrical generating power. Compared to other new-technology guns (such as rail guns), the main disadvantage of the system is its complexity. The CAP gun has the shortest barrel (for a given performance) of a series of weapons, including pure liquid-propellant guns and advanced conventional guns.

In this type of weapon, a sudden discharge of electricity heats the propellant in the breech to 5,000°C and causes an ion plasma to form. The oxidant is then added. The resulting combustion is more rapid than usual and adds almost 25 percent to the muzzle velocity of the weapon. That increase in velocity approximately doubles the range of the gun and greatly increases the energy of the shell at short ranges. In addition, because time of flight is reduced, fire control may be simplified for anti-missile defense.

Operational Characteristics. FMC won a US Army contract for a 110 mm electrochemical-gun demonstrator. The company has already demonstrated a 105 mm CAP gun with a muzzle velocity greater than 2,500 meters per second. For the Army, the issue is kinetic energy, since it is kinetic energy that penetrates tank armor. In contrast, a naval electrothermal gun would probably be optimized for high muzzle velocity to simplify fire control against fast maneuvering targets. Reduced muzzle energy could be accepted as long as the projectile was heavy enough to be lethal against a fairly flimsy target.

The CAP gun would benefit from the substantial electric energy output of the ship carrying it. FMC offers 9 megajoules at a muzzle velocity of 2,500 meters per second, or 18 megajoules at 1,700 meters per second, and 4.5 megajoules at 3,000 meters per second. FMC expects its CAP gun to be able to fire three rounds per minute for three minutes, and to fire 100 rounds between major component changes. Firing rate and duration are presumably limited, in part, by the electric power stored in the gun, although they are not nearly so severely limited as in a pure electromagnetic weapon.



SCSM Guided Round for 60 mm ET Gun

Source: Martin Marietta

Variants/Upgrades

In the naval portion of this program, United Defense focused on developing a 5-inch L54 electrothermal gun in two separate phases:

Phase I. The Phase I gun fires a 1.5 kilogram shell at 1,100 meters per second (4,940 ft/sec); the maximum mass accelerated is 14 kilograms.

Phase II. Fires a 4 to 6 kilogram shell at 1,500 meters per second (8,100 ft/sec); the maximum mass accelerated is 150 kilograms. Velocity is repeatable to within 0.15 percent in Phase I, and to within 0.5 percent in Phase II.

Lightweight 155 mm Liquid-Propellant Naval Gun Mount. In 1993, Martin Marietta announced a lightweight 155 mm liquid-propellant naval gun mount for this advanced gun program. It hopes to reach a range of 45 nautical miles with existing ammunition, and to exceed 100 miles with new projectiles, a rate of fire of 11 to 16 rounds per minute, and a velocity accuracy of better than 0.25 percent. It should then be able to fire a 4- to 8-round simultaneous impact mission at 6 to 40 kilometers. Range is increased because there is a capability to precisely inject propellant throughout the combustion process.

The system offers soft launch with reduced chamber pressure, and ammunition storage volume is reduced because there are no cartridge cases. Martin Marietta estimates that this 155 mm L52 will weigh 40,000 pounds (compared to 110,000 lb for an 8-inch L55), and will achieve a range of 54,000 yards. Elevation limits are +65 to -15 degrees; rate of fire is 16 to 29 rounds per minute with 60 ready-use rounds.

This development has since been at least partly overtaken by the introduction of the L62 barrel on the Mk 45 gun with the capability of firing extended range guided munitions (ERGM). The combination of extended barrel and non-ballistic guided munition will extend the gun's coverage to about 60 miles (100+ km).

Meanwhile, a new 155 mm gun mount is being developed (as a derivative from the USMC 155 mm unit); the DD(X) class will presumably be the first platform to adopt it.

Program Review

Background. In 1987, FMC (now part of United Defense) announced the development of its combustion-augmented plasma (CAP) technology for advanced gun development. Two major fields of exploitation were envisaged: long-range fire support for shore operations and close-range anti-missile defense. In the 1987 announcement, FMC showed its version of CIWS-2000, which used CAP and carried two rather than six barrels.

The first experiments used 10 mm projectiles. Later, 30 mm were used, and FMC expected to fire 90 mm projectiles. All of these experiments used liquid propellants, although a conventional solid propellant might also be used. In 1987, FMC applied its CAP technology to an Air Force funded hypervelocity ammunition technology (HAT) program in which a sideways-pointing anti-tank gun was to be mounted onboard a C-130 or successor gunship that would fly just behind the battle line. CAP was also proposed as part of a hybrid rail gun for anti-missile defense, to be used to inject a projectile into the electric gun.

FMC patented its CAP concept in 1985, and in 1990 it began a CAP naval gun project under the US Navy's Balanced Technology Initiative. The weapon developed under this program is designated the electrothermal gun, and is considered a much nearer-term proposition (e.g., for point defense) than a full electric gun. Compared to alternative exotic guns, CAP can use a conventional barrel and projectiles. FMC claims that CAP offers better reliability and internal ballistics control than a liquid-propellant gun.

In late 1990, the US Navy acknowledged the need for a new-generation close-in defense system to combat the latest anti-ship missiles. The use of electrothermal gun technology promised a new weapon that would use the same trunnion that housed the Phalanx system but offer significantly increased performance. Design work commenced in the last quarter of 1990, and was to be completed in the last quarter of 1991. A 31-month design contract valued at US$4.6 million was awarded to FMC for development of the new weapon in November 1990.

The FMC 60 mm electrothermal gun and its Martin Marietta (formerly GE) guided round small-caliber smart munition (SCSM) were tested successfully during 1992/93. The SCSM contract was awarded in the autumn of 1991. The 1.75 kilogram rolling-airframe steel shell (illustrated in this report) uses a K-band guidance uplink and an E/F-band telemetry downlink. It carries a thermal battery and a miniature propulsion

control using a small solid-propellant thruster. Muzzle velocity is 1.4 kilometers per second (4,260 ft/sec); SCSM can maneuver at 40*g* at Mach 4. Like Phalanx, this weapon kills by impact, not by explosion. Of the seven saboted projectiles successfully fired at Dahlgren Naval Base in the second half of 1992, five carried live gas generators and thermal batteries. The K-band command link was tested over water at Dahlgren in February 1993. Tests against airborne targets were scheduled for late 1994. The gun is an autoloader on a Phalanx mounting. Firing rate is 4 rounds per second/10 round burst); elevation limits are +40/-5 degrees.

Following a 30-month design and development program, the first 60 mm ET gun was delivered to the US Navy in July 1993. Following the completion of final NSWC acceptance trials, the gun, autoloader and other program elements – including propellant charges, guided projectiles and the TASD target acquisition system – will be integrated during a series of live firings against airborne targets.

In December 1994, the US Navy announced that it expected to make a decision on the feasibility of using electrothermal gun technology for future naval weapons by 1998. The studies, costing some US$107 million, would determine if a 155 mm electrothermal gun would provide a feasible, practical, and affordable solution for the US Navy's naval surface fire-support requirements. The study program would use a 5-inch L54 Mk 45 mount as a design baseline to evaluate the technology issues involved. The objective is to increase the gun range from its existing 27 kilometers to a maximum of 150 kilometers, and to integrate this improved performance with a new guided round.

However, by mid-1996, the whole US Navy side of this program was strongly de-emphasized in favor of the Army-related aspects. No work was being carried out on the naval weapons and no early introduction to service was predicted by company officials.

The performance increments gained by the introduction of combustion-augmented plasma technology are evolutionary rather than revolutionary, but, combined with the development of practical guided projectiles, are sufficient to restore a substantial measure of credibility to gun-based CIWS. The application of CAP technology to basic conventional gun designs means that the 60 mm ET-gun technology demonstrator should be adaptable to a service weapon within the forecast period. The timing of such a program will be determined by funding constraints. At present, other priorities are considered more pressing.

In all, the de-emphasis of the US Navy part of this program reflects, to some extent, the pressing urgency of near-term improvements in naval gunfire support capability at the expense of longer-term prospects. The now-canceled Arsenal Ship would have required the provision of a long-range gun. This could have been obtained more economically by introducing limited improvements to the existing 5-inch L54 Mk 45 (i.e., lengthening the barrel to L62) rather than by introducing an entirely new technology (i.e., ET). Also, the medium-range and saturation bombardment requirements could be better met (in the short term) by using a longer barrel and/or extended range guided munitions (ERGM).

The Mk 45 gun was recently upgraded with the introduction of a more powerful L62 barrel, answering some of the areas that the ET gun would have covered if it had proceeded as originally planned. This new, longer-range, more powerful version of the gun appears to be giving the Mk 45 program another shot in the arm. It is being sold to foreign navies, including the new destroyers of South Korea.

The US Navy's DD(X) that has replaced the canceled DD-21 Zumwalt class will use the new 155 mm Advanced Gun System for its main gun.

Reportedly, tests have shown that the power requirements of the electrothermal and electrothermal-chemical gun systems are still proving too substantial to be handled by naval platforms. Their adoption into service would require the addition of a substantial shipboard power generation capacity, probably a dedicated gas turbine. In addition there were growing concerns over the safe handling of the of the electrothermal and electrothermal-chemical ammunition in a shipboard environment. As a result of these considerations, the Navy eventually discontinued its active research on the subject in the late-1990s. The Navy has, however, continued to monitor the development of the relevant technologies for any possible advances in the ET gun field.

Funding

This program has been funded under the Federally Funded Research and Development Center (FFRDC) for Electromechanics and Hypervelocity Physics. Research and development funding was averaging at around US$2.9 million per year in the mid-1990s.

Recent Contracts

Contractor	Award ($ millions)	Date/Description
FMC	7.7	September 1991 – CPFF (SS) Increment for Electric Enhancement Factor, Electrothermal Chemical (EEF ETC) Gun program. (DAAA15-91-C-0124)
Martin Marietta	N/A	September 1991 – Development of SCSM for ET guns based on Phalanx.
Science Applications	10.58	June 1994 – Contract for the development and engineering of cartridges for electro-thermal guns. Work to be finished by April 1998.
Martin Marietta	17.2	October 18, 1994 – Navy contract for the design, development, and testing of a 155 mm technology demonstrator liquid-propellant gun, with an estimated completion date of August 1996. Contract extends through May 1997 and is an element of the Naval Surface Fire Support mission.

N/A = Not Available

Timetable

Month	Year	Major Development
	1985	Design work commenced
	1987	Martin Marietta reveals CAP gun design
	1990	US Navy takes up concept
	1991	First tests conducted
	1992	Gun mount integration; test firing to determine muzzle energy performed
Jul	1993	First gun delivered to US Navy
	1994	NSWC test and evaluation program
	1996	Naval work de-emphasized in favor of Army developments
Feb	1996	United Defense begins replacement of Mk 45 barrel with 62-cal, ERGM
Aug	1996	Projected start of liquid-propellant gun testings
	1997	First 5-inch conversion kits delivered; 155 mm prototype readied
	1998	ET-gun research reported to have been terminated (for ERGM, L62, VGAS)
FY	1999	Vertical Gun for Advanced Ships (VGAS) program launched
Feb	2000	Navy invites R&D for future ship advanced gun propulsion concepts
	2001	Initial Operational Capability for 5 inch Mk 45/L62 version
April	2002	Contract placed for final design of DD(X)

Worldwide Distribution

None are in service at this time. (This program is in the process of observing competitive technologies and possibly involves minor research; it is not aimed at imminent production for the moment.)

Forecast Rationale

The story of the of the electrothermal and electro-thermal-chemical guns contains an important lesson. No matter how attractive a new technology is, if it doesn't satisfy a real operational requirement in a timely and satisfactory manner, and doesn't perform better than any rival technology, then it won't be accepted for service use. Neat technology is not enough – success demands neat and appropriate technology. Naval adoption of the of the electrothermal and electrothermal-chemical concepts has not taken place

because they faced rivals that could fill the same operational niches at lower cost and technical risk.

One of these niches is land attack. In this area, naval guns are regaining the ground they had lost to missiles since the end of the Second World War. This process was started by the shift of the anticipated future naval combat theaters into the coastal regions of the world, as a support function to land-bound forces. The War on Terrorism, with its emphasis on land attack and special forces operations, has reinforced that trend. However, the role that electrothermal and electrothermal-chemical munitions may have played has been filled by the interim solution of the 62-caliber 5-inch Mark 45 gun and the longer-term 155 millimeter AGS solution. Fitted with non-ballistic (gliding) guided shells, these guns fill one niche appropriate to the electrothermal and electro-thermal-chemical guns.

The other possible application for electrothermal and electrothermal-chemical technology was point defense against inbound anti-ship missiles. This role has fallen victim to the general trend away from guns for this role and the preference for missile-based solutions. Missiles offer greater engagement rates and longer intercept ranges than any plausible gun-based system. In addition, the ship impact of the missiles is much less than that of the electrothermal and electrothermal-chemical guns. This is particularly the case in terms of electrical power supply. Warships are already power-critical, and the imposition of another voracious consumer of power to the already-overloaded shipboard generation suite would need either significant justification or a major technology change.

That change may be provided by the US Navy decision that future combatants will be powered by an all-electric propulsion system in lieu of today's gas turbine-based systems. This means the role of the gas turbine will shift to being onboard only as producer of electric power for both onboard systems and ship propulsion. If this technology fulfils its promise, it would solve much of the power-shortage problem on modern warships. That is, however, a long way from suggesting that it would make the electrothermal and electrothermal-chemical guns operationally desirable.

In conclusion, the electrothermal and electrothermal-chemical gun and its future permutations are not dead as concepts and are still being evaluated as potential weapons. However, their transition from interesting concept to practical weapon will depend upon them fulfilling a real and definable tactical need better than any potential rival. That does not seem probable at this time. As a result, no production of an ET gun is expected within the forecast period. Research and development efforts, however, are likely to continue on a technology demonstration basis, and these may result in the evolution of practical weapons. accelerate in the outyears.

Ten-Year Outlook

No production is forecast yet; the program is in observation and development phase. The chart is therefore omitted.

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