KINETIC ENERGY TECHNOLOGY

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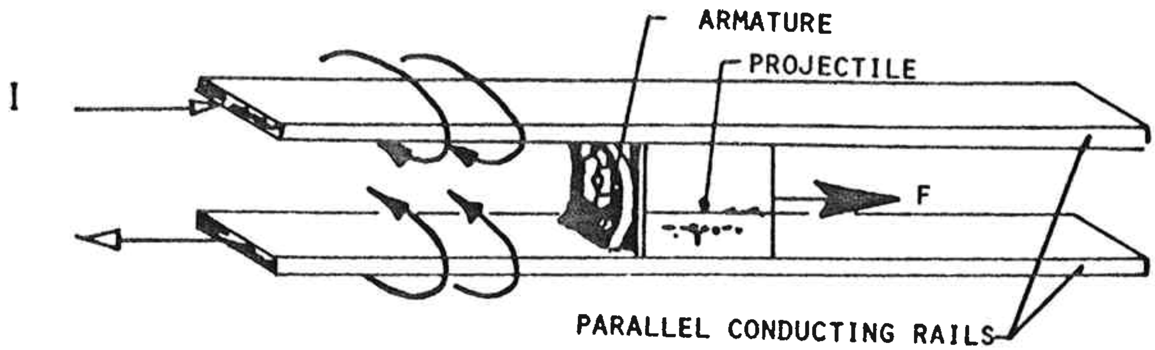
The Strategic Defense Initiative Kinetic Energy Weapons (KEW) program incorporates two distinct technologies: missiles (near term) and electromagnetic launchers (long term). Since missiles already have an established industrial base, only the recently emerging technology of electromagnetic launchers (EMLs) will be discussed here. In so doing, the efficiency and velocity limitations imposed by theromodynamic principles are avoided. EMLs are capable of achieving much higher accelerations and velocities and in some cases higher efficiencies than their theromodynamic counterparts. The technologies required are those of generating and conditioning the extremely high levels of pulsed electrical power needed. As we will see, these new EML technologies have a variety of potential commercial applications as well.[1]

The KEW program involves accelerating projectiles to velocities far in excess of those achieved by conventional guns, for the purpose of destroying ballistic missiles by kinetic energy impact. As compared with directed energy weapons (DEW), the lethality mechanism is less controverisal, but the longer time-of-flight makes actually hitting the target more difficult. This leads to the use of so-called smart projectiles, either command guided or terminally homing. However, the topic that will be discussed here will be the launch mechanism for such weapons.

ELECTROMAGNETIC LAUNCH TECHNOLOGY

EML technology generally can be divided into two approaches: the simplest being the railgun, the more complex and potentially more efficient being the coilgun. The electromagnetic railgun (Figure 14.1) consists of two parallel, metal rails separated by a distance typically equal to their width. A projectile with a conducting armature is placed between

Figure 14.1
Electromagnetic Railgun

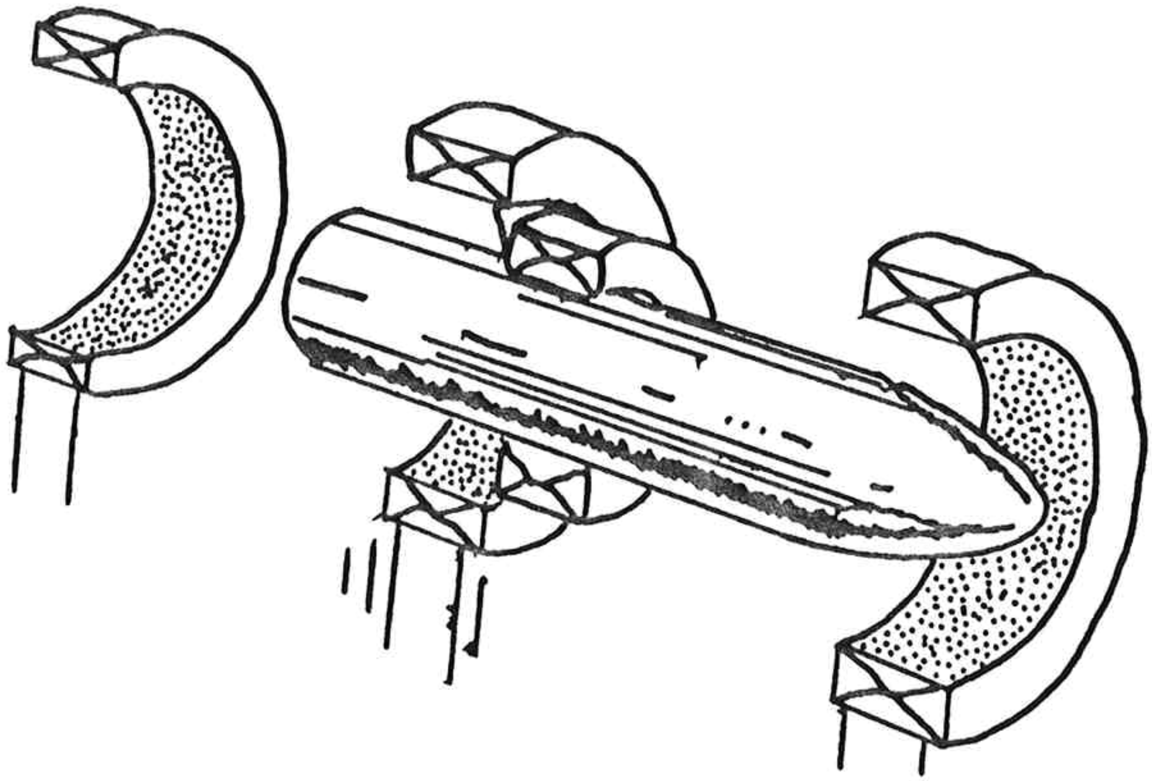


Source: All of the figures in this chapter were compiled by the author.

the rails at the breech of the railgun. If the breech of the railgun is then connected to an appropriate source of electrical current, the current will flow down one rail, across the armature and back up the other rail. The current flowing in the rails creates a magnetic field between the rails, and the current flowing in the armature interacts with this magnetic field to produce a force that accelerates the armature and projectile down the gun barrel. This accelerating force, known as the Lorentz force, reaches levels of interest only at extremely high currents ($> 10^5$ A). Unlike a thermodynamic gun in which the acceleration falls off as the hot gas expands, the acceleration in an EML can be held constant as long as constant current is maintained in the gun. Being the simplest of the EMLs, the railgun has enjoyed the most rapid development. In recent years, masses as high as 300 grams have been accelerated to velocities in excess of 4 km/s while smaller masses (1–5 g) have been accelerated to velocities of 8–10 km/s. For comparison, conventional guns are practically limited to velocities of 1.5–2 km/s.

Coilguns, while being more complicated than railguns, also offer the promise of higher efficiency and greater control over acceleration. The basic concept for a coilgun (Figure 14.2) involves a series of stationary (stator) coils and a moving (armature) coil attached to the projectile. As the armature coil passes through each stator coil, current is directed into the stator coil so that the armature coil is repelled down the gun barrel. A variety of coilgun configurations have been considered that differ in the way current is supplied to the stator and armature coils. The coilgun is attractive since it does not require contact between the armature and stator, as the railgun does, and since its higher impedance leads to higher efficiency as mentioned previously. The additional complexity of the coilgun stems from the more complicated construction of the stator and

Figure 14.2
Electromagnetic Coilgun



the need to synchronize the current feed to the individual stator coils with the position of the armature.

PULSED POWER TECHNOLOGY

EMLs of interest require electrical power of hundreds of megawatts to several gigawatts during launch. Although the basic operating principles of EMLs have been known since the early part of this century, their enormous power needs kept then from being realizable until recent advances in pulsed power technology (PPT). PPT uses energy storage techniques to store energy slowly at moderate power levels and then deliver that stored energy in a brief, intense burst of electrical power. Energy may be stored electrostatically in capacitors, electromagnetically in inductors, electrochemically in batteries, or in the inertia of spinning flywheels. Recent developments at the University of Texas's Center for Electromechanics (CEM-UT) involving the incorporation of specialized rotating electrical generator technology with inertial energy storage have made compact, inexpensive, portable pulsed power supplies available for driving EMLs. Of course, the pulsed power supply must do more than just store energy. It must deliver the desired current at the appropriate voltage level in exactly the proper time frame. Two CEM-UT developed power supplies are capable of performing this crucial task for a variety of EMLs as well as other applications. The first of these is the pulsed homopolar generator (HPG). Although the basic concept is over 150 years old, a portable HPG pulsed power supply has only recently become practical. Figure 14.3 shows the principle of HPG operation. As a monolithic conducting rotor (flywheel) spins in an axial magnetic field a voltage is generated between the shaft and outer periphery of the rotor. If sliding contacts are applied to the shaft and rotor periphery, the generated voltage can be utilized to drive a current in an external circuit. As electrical energy is extracted from the HPG, the rotor slows because its inertial energy is being converted to electrical output.

A second CEM-UT developed pulsed power supply, the compulsator, was invented in 1978. Whereas the HPG produces a single output pulse as it slows, the compulsator produces a burst or a continuous chain of pulses. The rotor and stator of a compulsator are now under construction at CEM-UT. This machine, which is designed to power an electromagnetic machine gun, will produce a burst of ten 2.5-kV, 1-MA, 2-ms pulses in one-sixth of a second.

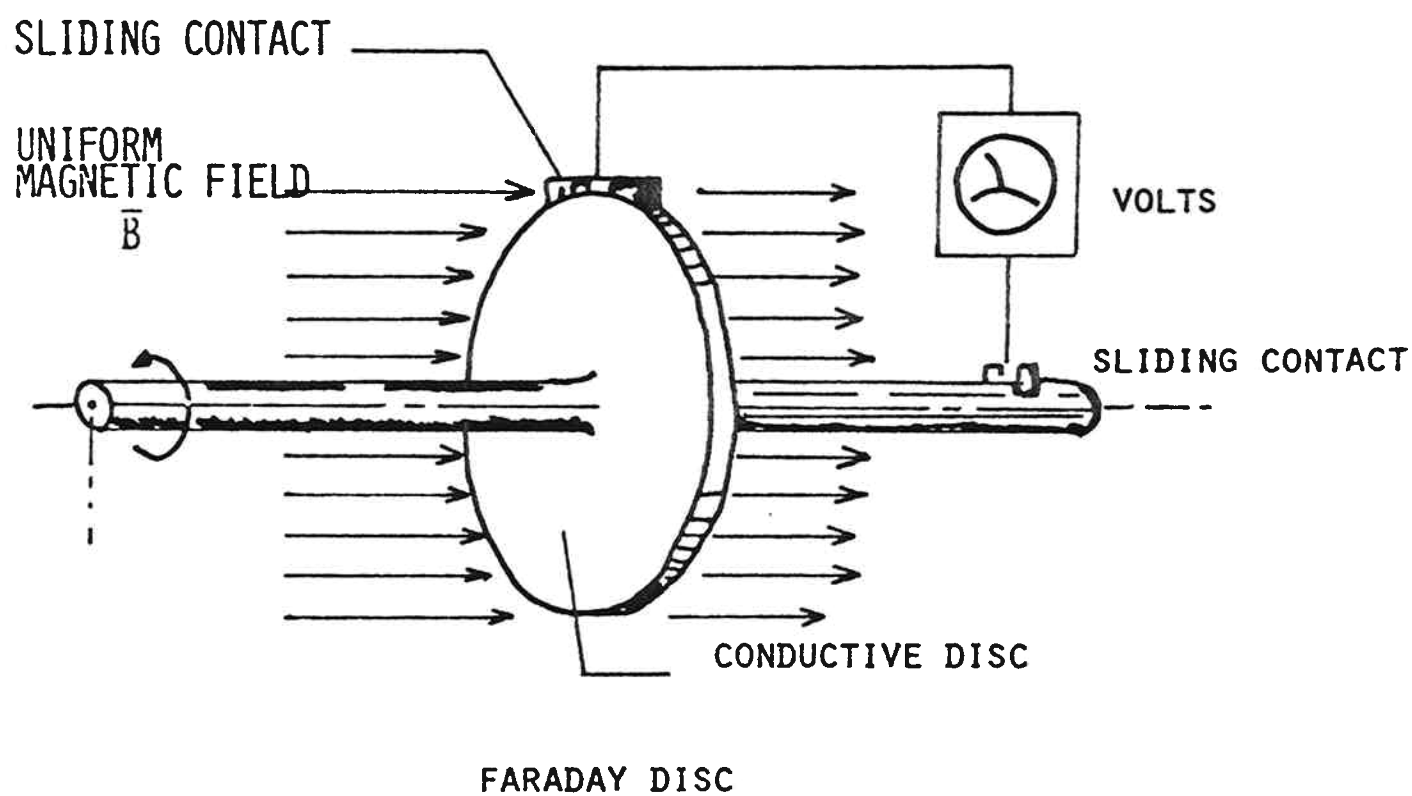
EML TECHNOLOGY APPLICATIONS

In addition to strategic kinetic energy weapons, EMLs are being investigated for tactical weapons including artillery, antiarmor, and air defense. The technology is being developed for launching aircraft as well and has been considered for launching payloads into space. A pound of material can be fired into low earth orbit for 65 cents worth of electricity compared to a cost of $4,500 per pound for the space shuttle. EMLs have even been studied for propelling advanced space missions. For this application the EML would be used instead of a rocket engine since it can propel the exhaust material at higher velocities than a rocket and, therefore, achieve the desired propulsive force with the expenditure of less mass.

But EML technology has more down-to-earth applications as well. Metal powders fired from railguns have more than sufficient kinetic energy to melt upon impact, producing dense coatings that are tightly bonded to substrates. When coupled with the rapid-fire pulse capability of the compulsator, this metal-spraying process may some day provide an alternative to welding and casting or forging of metal parts. By varying powder composition during spraying, monolithic parts might be made with customized properties in different areas. Ceramic powders can be sprayed by this technique as well.

Since railguns easily impart to projectiles kinetic energies sufficient to

Figure 14.3
Homopolar Generator



melt or forge them (at 3 km/s the kinetic energy density in a projectile exceeds the energy density in high explosives), it is conceivable that EMLs might be used to form, forge, or draw metal ingots into desired shapes, perhaps using noncontacting magnetic dies. Since tactical EM guns will be capable of penetrating substantial thicknesses of armor plate, the same technology might be used for drilling deep holes or tunnels through the earth. As deeper wells are drilled, for example, the ability to transmit drilling power down the hole becomes a limiting factor. A compulsator-powered railgun on the surface could fire hundreds of rock-penetrating projectiles per second down a well. The limiting factor on drilling speed, in this case, might well be the rate at which debris could be removed from the hole.

CEM-UT pulsed power supplies developed primarily for EML applications have potential commercial applications as well. HPGs have been used to produce high-quality welds in large metal sections in a fraction of a second, heat metal billets for forging and rolling applications, and sinter metal powders into monolithic parts. Magnetic forming of metal parts is another potential application of HPG technology. The compulsator, originally invented for powering xenon flashlamps to drive solid-state lasers, might also be used to flash similar lamps rapidly for high-speed drying of paint or printing ink.

Electromagnetic launch technology and the closely related pulsed power technology are newly emerging fields with a wide variety of potential applications. It is the mission of the CEM-UT to develop the required technology base, perform preliminary investigations of promising applications, and transfer technology to the industrial sector, working closely with industrial and government sponsors to accomplish these goals.

NOTE

1. Richard A. Marshall, "The Acceleration of Macro Particles and a Hypervelocity Macro Particle Accelerator," Ph.D. Thesis, Australian National University, Canberra, 1972.