

Hypervelocity Electromagnetic Gun Development at CEM-UT

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INTRODUCTION

Interest in railguns at the Center for Electromechanics at The University of Texas at Austin (CEM-UT) was the result of a visit to the railgun facility at the Australian National University (ANU) at Canberra in 1979. Soon after that visit the concept of a Distributed Energy Store (DES) railgun was invented and the first injected railgun was tested at CEM-UT. When railguns were introduced into the defense community in 1980, the technology started to grow in the United States. With the announcement of the Strategic Defense Initiative (SDI), electromagnetic launcher research took another quantum step. Today CEM-UT is actively testing state-of-the-art launchers on the pulsed power supplies developed at CEM-UT over the past twelve years. In addition, CEM-UT is preparing for the future with the installation of the Balcones Homopolar Generator Power Supply and by maintaining programs in state-of-the-art rep-rated power supply development and hypervelocity launch. A detailed description of the CEM-UT facility is presented in Appendix A at the end of the text.

HYPERVELOCITY LAUNCH DEVELOPMENT

Railguns were introduced to CEM-UT in early 1979 as a result of a visit to the railgun facility at ANU. The first guns were small models built from copper and G-10 stock and powered by low-voltage computer-grade electrolytic capacitors. Richard Marshall joined CEM-UT in 1979; shortly thereafter, he and William Weldon invented the concept of DES guns (Figure 1, Ref. 1). The concept provides enhanced efficiency in the launchers and the ability to power long launchers for such experiments as space launch and hypervelocity impact studies. To further improve the efficiency and better control rail erosion, a shotgun-styled injector was developed for the electric gun. The first DES gun and the first injected railgun were built and tested at CEM-UT in 1981 (Ref 2). Interest in electromagnetic guns grew slowly in the United States until the technology was introduced into the defense community in 1980. In 1982 a series of joint experiments with CEM-UT and General Dynamics produced the first homopolar generator inductor (HPG/I) powered railgun (Figure 2, Ref. 3) to operate at CEM-UT.

In August 1982, railgun experiments operating in vacuum were exploring the formation of noncrystalline material by hypervelocity impact. The testing was also investigating the possibility of alloying the surface of targets with impacting materials to form wear resistant coatings (Ref. 4). The program was an effort to introduce railguns to industry. Work on the DES concept continued and in July 1983 a 10-stage, 3.6-m long DES gun was tested. A 1-g lexan projectile was accelerated to 3 km/s in this launcher (Ref. 5). In August 1984 General Dynamics returned to CEM-UT to perform the first test of a rep-rated railgun using the HPG/I system. As interest grew in high rate of fire systems the compensated pulsed alternator (compulsator), originally designed by CEM-UT to power laser flashlamps, was studied for its suitability to drive an electromagnetic gun (Figure 3, Ref. 6). The machine has a rotating excitation and several multiturn compensated lap windings all connected in parallel on the stator. Compulsators can supply high-current pulses at high frequencies. Pulse widths from 500 μ s to several ms are readily obtainable. The output pulse from the machine has a natural current zero to ensure current interruption as a projectile exits the muzzle of the gun. Since the machine generates several kilovolts, no external power conditioning is required. This technology in itself has spawned the development of special enhanced railguns that match well

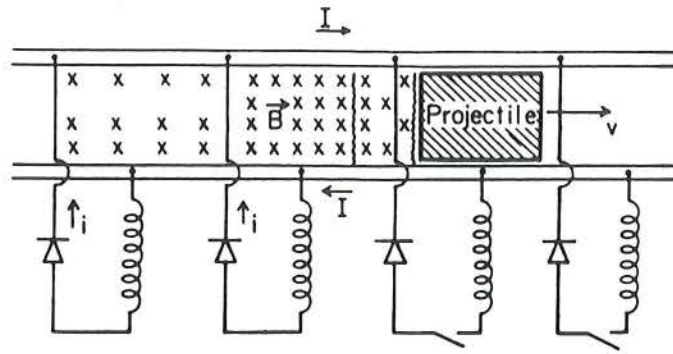


Figure 1. Distributed store railgun

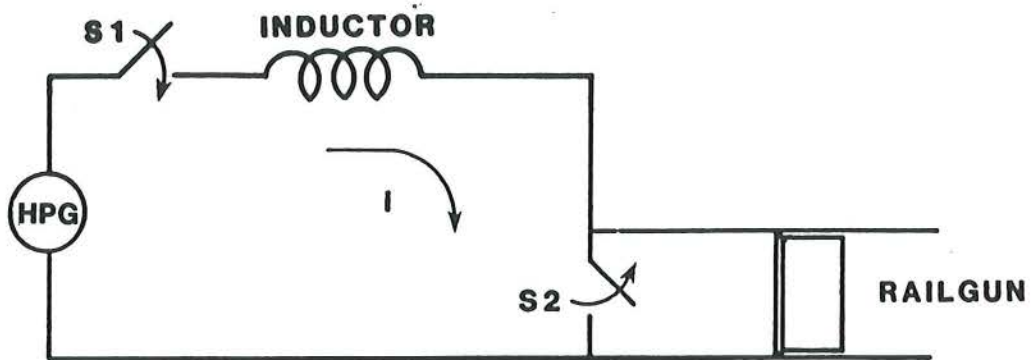


Figure 2. Simple inductive transfer circuit

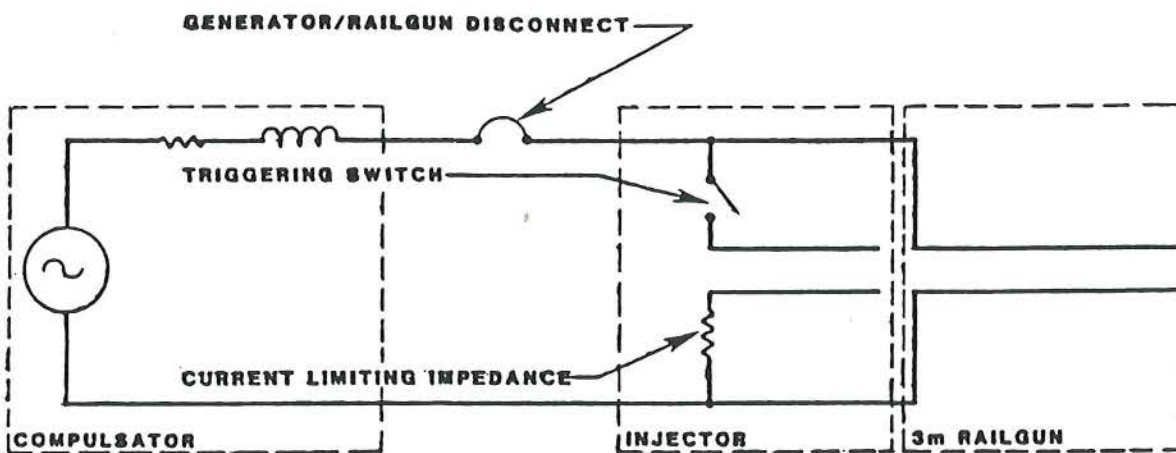


Figure 3. Schematic representation of compulsator-injector-railgun

the compulsator impedance. The compulsator is expected to be the workhorse power supply for tactical railgun systems.

The next year at CEM-UT would see five new launcher concepts designed, fabricated and tested, the equivalent of all previous railgun projects. The technology was accelerating largely due to defense funding from SDI. The goals within SDI involve short time of flight, guidance, and verifiable lethality. The hypervelocity program at CEM-UT will attempt to investigate railgun speeds in the 50-100 km/s regime and projectile masses sufficient to provide verifiable kinetic energy kill. CEM-UT developed a concept whereby a dense metal vapor plasma could be accelerated to high speeds in a rail launcher. To test the principle, a 0.5-m coaxial railgun was developed and tested in April 1984. Approximately four milligrams of mass was accelerated to 22 km/s in this test (Ref. 7). A 5-m version of the coaxial railgun was then fabricated and tested in September 1984. Increasing the bore size, vaporized mass, and energy delivered did not increase the accelerated plasma mass or its lethality. Experiments with magnetic field to concentrate the plasma and keep it from interacting with railgun sidewall are underway.

Before magnetic focus techniques and the complexity they imply are applied to large-scale launchers, tests are underway to accelerate solid projectiles to high velocity. The problems are severe in that small solid projectiles imply small railgun bores, yet to reach high velocity in reasonable gun lengths, large currents must be used. The stresses developed in the anisotropic structure of the parallel rail launcher are immense. A high-pressure launcher from Los Alamos Scientific Laboratories (LASL) was brought to CEM-UT in February 1985 to test candidate low-density projectile materials such as carbon foam, carbon reinforced carbon fiber, and foamed glass. While experience was gained with this launcher, a disassembleable high pressure gun to test railgun and projectile materials was designed and fabricated. (Fig. 4) The first test with this gun conducted in July 1985 have accelerated a 3-g glass-filled polycarbonate projectile to 4.3 km/s in a 1-m gun.

CEM-UT has established a reputation by developing pulsed power supplies. Bringing the power supplies developed over the past twelve years together with the railguns has created new research opportunities in hypervelocity launch. The workhorse supply at this time is a 10-kV, 0.6-MJ capacitor bank. As switching is developed, the higher energies available in a 6-MJ HPG charging a 3-MJ energy storage inductor at one megampere will boost the railgun research into a new test

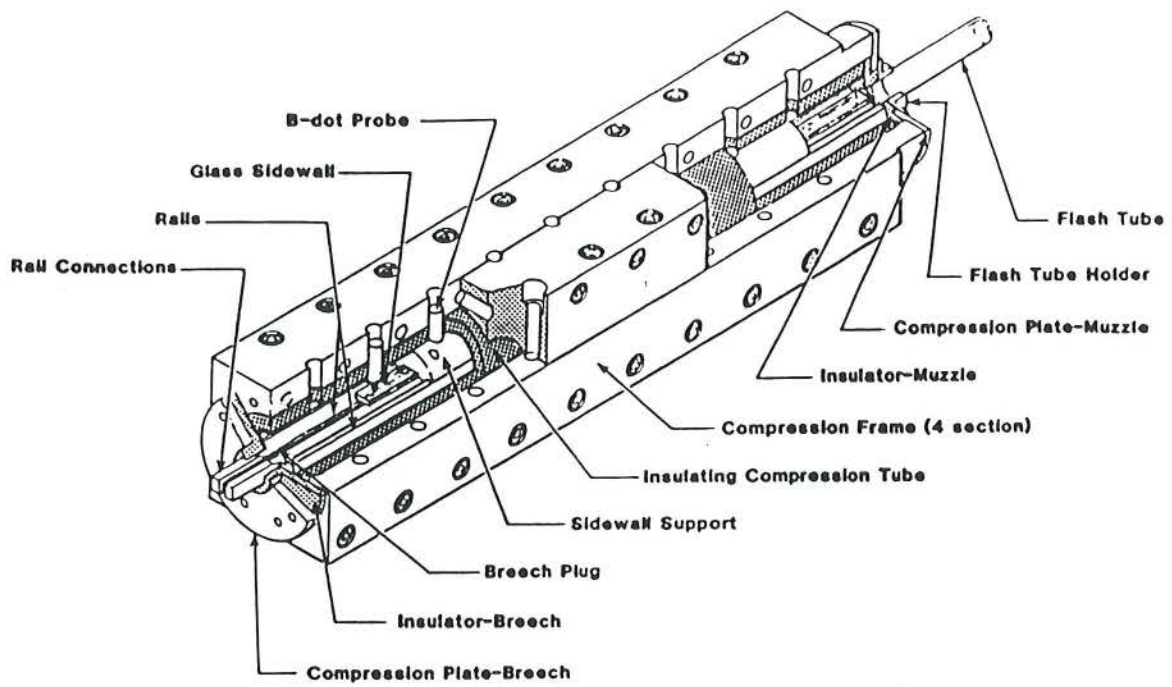


Figure 4. One meter square-bore railgun

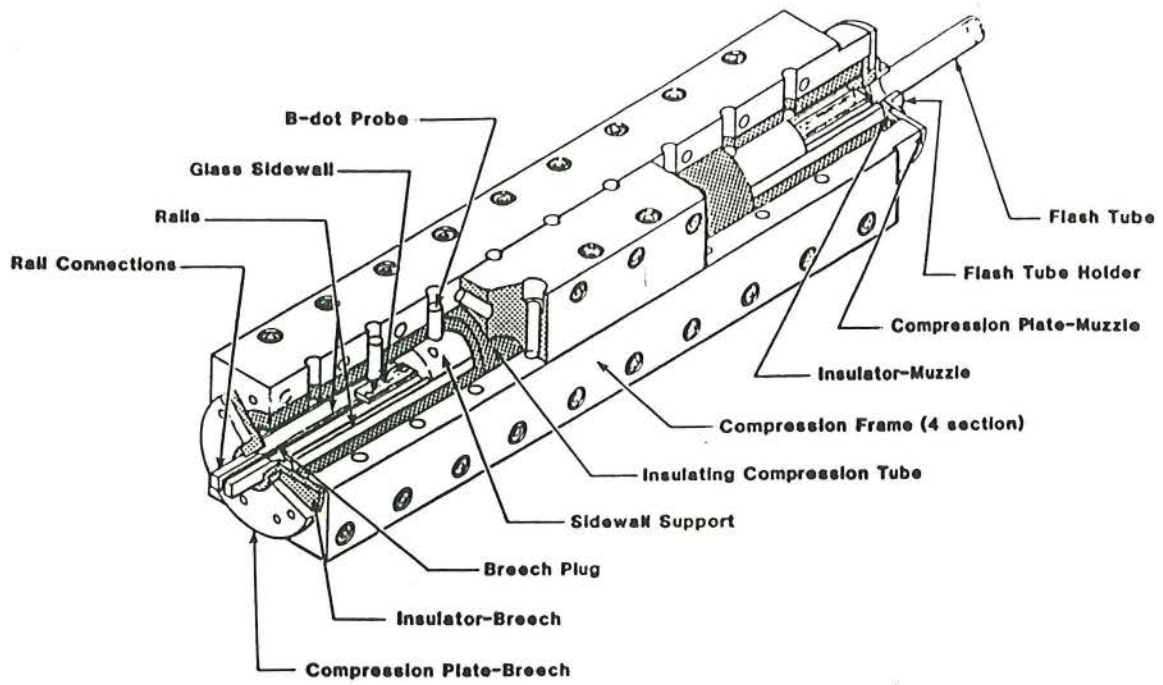


Figure 4. One meter square-bore railgun

regime. Currently, the Balcones facility of CEM-UT consisting of a 60-MJ HPG with 30 megajoules of inductive energy at six megamperes has been designed and is under construction. This timely power supply development will allow the testing of future launchers whose designs will be based on the results of a progression of well-related experiments.

REFERENCES

1. L. D. Holland, "The CEM-UT Distributed Energy Store Railgun Facility," Fourth IEEE International Pulsed Power Conference, Albuquerque, NM, June 6-8, 1983.
2. R. A. Marshall, "The CEM-UT Distributed Energy Store Railgun: Report on the Two-Stage Version," Report, Texas Atomic Energy Research Foundation, July 1981.
3. R. C. Zowarka, R. A. Marshall and W. F. Weldon, "Energy Stores and Switches for Rail Launcher Systems," NASA/Lewis Research Center, Grant No. NAG-3-303, October 1, 1982 through September 30, 1983.
4. M. L. Spann and L. D. Brown, "Formation of Amorphous Metal by Hypervelocity Impact," Thin Solid Films, in press.
5. L. D. Holland, "Distributed Energy Store Railguns Experiment and Analysis," Dissertation, Faculty of the Graduate School of The University of Texas at Austin, Vought Corporation, Purchase Order #6234, August 6, 1982 to April 15, 1984.
6. M. L. Spann, S. B. Pratap, and M. V. Vaughn, "Research and Development of a Compensated Pulsed Alternator for a Rapid Fire Electromagnetic Gun,: Interim Report, U. S. Army Armament R & D Command Contract No. DAAK10-83-C-0126, July 12, 1983 to April 15, 1984.
7. W. F. Weldon, J. H. Gully, and R.C. Zowarka, Jr., "Development of an Ultrahigh Speed Electromagnetic Accelerator," Interim Report, U.S. Army Armament Research and Development Center, Contract No. DAAK10-83-C-0127, October 7, 1983 to July 15, 1984.

APPENDIX A
Facilities and Capabilities

CEM/CES FACILITIES AND CAPABILITIES

Experimental Systems

- Homopolar Generators. 60-MJ modular system of six 10-MJ drum-type units. Various series-parallel combinations yield terminal voltage to 600-V. Others include: 10-MJ disc-type, 6.2-MJ compact, 5.0-MJ HPG System Tester, and 3.0-MJ high voltage (superconducting field coil).
- Compulsators. DARPA/ARDC device - 1-MJ per pulse, 60-Hz firing rate, burst rated. Also active rotary flux compressor, 100-kJ per pulse, 60 Hz, burst rated.
- Energy Storage Inductors. 6 μ H, 1 MA, cryogenic coaxial and 10 μ H, 500 kA, cryogenic Brooks coil.
- Capacitive Energy Stores. Ten modular stores at 55 kJ each, 10 kV, 1 MA total peak output current. Other lower current wave forms of longer duration produced by distributing discharges in time.

Electromagnetic Launchers

1. Coaxial, high-vacuum plasma accelerators; 0.5 and 5.0 meter long.
2. Three-meter multi-barrel burst-rated projectile launcher with electromagnetic injector (DARPA/ARDC device).
3. One-meter square bore high pressure rebuildable launcher.

Instrumentation and Control

1. RFI/EMI shield room with filtered, uninterruptible power.
2. Fast event recording (48 channels).
3. Digital oscilloscope (56 channels)
4. Twelve control computers.
5. 40-MB local data storage.
6. 1.3-GB central data storage.
7. Automatic data reduction/plotting.
8. Hard copy oscillographs (72 channels).
9. Magnetic tape storage (56 channels).

Analytical and Modeling Capabilities

1. Steady state and transient, non-linear, two and three dimensional magnetic field code capability including force and stress computation, eddy current generation, and thermal effects.
2. Performance modeling and design capabilities for electromagnetic accelerators, homopolar generators, compulsators, inductive energy stores, and opening switches.

Utilities

42-MW electric (85-MW by 1987), 0.5-MW compressed air, 4.2-MW chilled water, 2.1-MW hydraulic at 6,000 psi; 600-kW steam, 400-kW emergency power, bulk LN_2 storage with distributed boil-off.

Special Test Facilities

1. Controlled environment sliding contact test system.
2. Tribology laboratory.
3. Rotating machinery laboratory.
4. High voltage test facility.
5. Explosives test facility.
6. Flash X-ray photography.

In-House Services

1. Chemical and metallurgical analytical services.
2. Electronics shop.
3. Precision machining, plasma spraying, plasma cutting.
4. Computational and data storage mainframe computers.
5. Publication production.
6. Conference facilities (750 people).

Special Features

1. 50-, 25-, 6-, and 3-ton bridge cranes, interconnecting.
2. Six-m diameter x 6-m deep covered floodable test pit.
3. 450 acre site allows for future expansion.
4. Low impedance, fault-rated grounding system.
5. Extensive fire prevention/safety systems.
6. CCTV monitoring of experiments.

Net Square Footage

Office and Administration	24,600
Shops	8,000
Low Laboratories	17,000
High Laboratories	<u>14,520</u>
TOTAL	64,120

Facility Clearance

Office space	1,000 sq. ft.
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Planned Facilities

Supercomputer	5/86
Controlled environment chamber	9/86
85-MW Electric power	4/87