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AUTHOR(S): G. M. Fowler, D. R. Peterson, R. S. Hawke and A. L. Brooks

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Post Office Box 1663 Los Alamos, New Mexico 87545

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RAIL GUN DEVELOPMENT FOR EOS RESEARCH*

C. M. Fowler and D. R. Peterson
Los Alamos National Laboratory, Los Alamos, NM 87545

R. S. Hawke and A. L. Brooks
Lawrence Livermore National Laboratory, Livermore, CA 94550

ABSTRACT

We give the status of a railgun program for EOS research in progress at Los Alamos and Livermore National Laboratories.

INTRODUCTION

We will discuss in order, the operating principle of rail guns, the power supplies used to drive them, diagnostic techniques used to monitor their performance and initial efforts to develop projectiles suitable for EOS research. We conclude with a table that contains available and projected facilities and diagnostics, recent studies and personnel presently associated with the program.

OPERATING PRINCIPLES

Fig. 1 shows the basic components of a square bore rail gun. The projectile is placed in the gun breech, just forward of a metallic fuse. When power is supplied, the fuse vaporizes and a current arc forms behind the projectile. The resulting force on the projectile is approximately $F = L'I^2/2$, where I is the current and L' is the rail inductance per unit length. For a square bore L' is typically a few tenths $\mu\text{H/m}$.

* Work done under the auspices of the US Department of Energy.

Fig. 1. Two views of a square-bore rail gun.

POWER SUPPLIES

Railgun power supplies should be able to deliver large currents (up to MA's) for large times (up to several ms). Among those used are homopolar generators, capacitor banks and flux compression generators. The latter two systems are used in the present program.

1. Capacitor Bank

A 400 kJ, 30 mF, 5 kV capacitor bank is used as a direct power source. Large capacitance, low voltage banks are better suited for railgun applications because the current pulses are longer and voltage breakdown between rails is less likely than for higher voltage banks of equal energy.

2. Flux Compression Generators

Figure 2 shows the flux compressor presently used. The explosive strip overlaid on the upper copper conductor is detonated after magnetic flux is introduced into the generator by a capacitor bank (940 kJ, 25 KV max). As detonation proceeds, the upper copper conductor is driven into the lower conductor pushing the flux into the railgun load.

RAILGUN PERFORMANCE DIAGNOSTICS

Diagnostics include magnetic probes and light pipes to monitor projectile motion in the gun, flash x-radiography to photograph the projectiles in free flight, Rogowski loops to obtain the current time history, and muzzle voltage measurements.

Figure 3 shows a 1.2 m long rail gun (the rails are potted in a strong pipe for strength) with cables from magnetic probes (top) and light pipes (below). Figure 4 shows an x-radiograph of a cubical lexan projectile in free flight. On Fig. 5 are plotted current-time records obtained for 3 gr lexan projectiles accelerated to about 5.5 km/sec (lower curve) and one projected to be about 10 km/sec (upper curve).

Fig. 2. Schematic of flux compression strip generator.

Fig. 3. 1.2 m long rail gun showing various probes.

Fig. 4. Flash x-radiograph of lexan cube in free flight.

Fig. 5. Current time curves.

Figure 6 shows the internal consistency of some of the diagnostic data. The horizontal time ordinates are 100 μ s per division. The solid curves were calculated by integrating the force equation using measured current-time records. Other diagnostics fit these curves well including the flash x-ray diagnostics, muzzle voltage discontinuities, and magnetic probe and light-diode signals (not shown). Similar agreement was largely obtained for the projected 10 km/sec shots. However intact projectiles were not seen on the x-radiographs and it was concluded that the projectiles broke up.

Figure 7 shows a lexan sabot with an inset Ta impactor, subsequently accelerated to 2.4 km/sec. However, a flash x-radiograph showed that the impactor became separated from the sabot.

Fig. 6. Distance vs time for 3 gr lexan cubes. The horizontal time ordinates are 100 μ s per division.

Fig. 7. Photograph of a lexan sabot with Ta insert.

TABLE I

Joint Los Alamos/LLNL Railgun R&D Effort

Laboratory Facilities	8-30 mm bore electromagnetic rail guns (expected velocity range 5-25 km/s). Powered by 940 kJ, explosive driven magnetic flux compression generators.	
	8-12 mm bore electromagnetic rail guns (expected velocity range, 5-20 km/s). Powered by 400 kJ, (30 mF, 5 kV) capacitor bank.	
Diagnostics	<ul style="list-style-type: none"> • Pins for shock arrival • Fiberoptic coupled photodiodes for plasma arc passage • Railgun current and voltages for gun performance • Laser beam for projectile launch • X-ray and optical diagnostics 	
Recent Studies	<ul style="list-style-type: none"> • Railgun performance studies • EOS diagnostics and railgun compatibility studies • Impactor launch demonstration • Rail and dielectric lifetime studies • 5.5 km/sec intact projectile launch 	
Principal Investigators	Los Alamos	LLNL
	C. M. Fowler	R. S. Hawke
	D. R. Peterson	A. L. Brooks
	J. W. Shaner	A. C. Mitchell
Technical Support	Jim King	Neil Gibson
	Richard Martinez	Peggy Lorton
	Barbara Fox	Martin Roeben
	Dennis Shampine	Craig Wozynski
	Jerry Kerriak	Gin Yee
	Charles Cummings	