CONF-790709--4

MASTER

PREPRINT UCRL- 82296

Lawrence Livermore Laboratory

PROSPECTS FOR GENERATING 1-10 TPa
PRESSURES WITH A RAILGUN

R. S. Hawke
J. K. Scudder

July 13, 1979

This paper was prepared for presentation at the
VIIIth International High Pressure AIRAPT Conference
July 30 - August 3, 1979
Le Creusot, France

This is a preprint of a paper intended for publication in a journal or proceedings. Since changes may be made before publication, this preprint is made available with the understanding that it will not be cited or reproduced without the permission of the author.

PROSPECTS FOR GENERATING 1-10 TPa

PRESSURES WITH A RAILGUN*

R. S. Hawke

J. K. Scudder

Lawrence Livermore Laboratory

Livermore, California 94550

Abstract

It has been demonstrated that a plasma arc can be accelerated along two current carrying parallel rails and used to accelerate a projectile.¹ We have performed an extensive analysis and found the task of using a railgun to accelerate an impactor plate to velocities of 10-40 km/s to be feasible with contemporary technology. This range of impact velocities would enable shock pressures of 1-10 TPa to be generated for EOS research.

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

*This work was performed by the U. S. Department of Energy
by the Lawrence Livermore Laboratory under contract number
W-7405-ENG-48.

PROSPECTS FOR GENERATING 1-10 TPa

PRESSURES WITH A RAILGUN

R. S. Hawke

J. K. Scudder

Lawrence Livermore Laboratory

Livermore, California 94550

Extended Abstract (invited paper)

The magnetic railgun is essentially a linear dc motor consisting of a pair of rigid parallel conductors that carry current to and from a small interconnecting movable conductor. The connecting link functions as an armature while the parallel rails serve as a single-turn field winding. The force F on the armature is given by,

$$F = \frac{L_1 I^2}{2} ,$$

where I is the armature current, and L_1 is the inductance per unit length of the rail pair. A typical "square bore" configuration, where the rail separation w is equal to rail height h , has an L_1 equal to $\sim 0.42 \mu\text{H/m}$. Thus a 10^6-A current will produce 2.1×10^5 Newtons of thrust on the armature.

We have examined the fundamental and technical issues that are believed to control dc-railgun efficiency and performance.² Topics considered included resistive heating and magnetic loading of the parallel rails; stress considerations within the rail support structure; interior ballistics of the projectile, including dynamic loading and drag; and, finally, estimates of launcher performance as a function of input energy. It was found that limits result from the properties of the rail and projectile materials, interior ballistics of the projectile, and available energy.

Table 1. Summary of anticipated Limitations

Limiting factor	Limit	Value Used
Rail melting (copper)	1083 C - $I/p = 43$ kA/mm	16 kA/mm
Rail yielding (steel)	1 GPa - $I/w = 75$ kA/mm	75 kA/mm
Sabot failure (graphite composite)	1.4 GPa- $I/w = 81$ kA/mm	75 kA/mm
Projectile stability	$A_R = 0.5$	0.5

where, p is the perimeter of the rail cross-section, and A_R is the aspect ratio of the projectile.

We have simulated the railgun operation with a computer code. The code accurately reproduced the performance of the ANU¹ railgun and is used here to predict operation at velocities >10 km/s.

The railgun simulation code was used with the limitations described above to determine the expected performance of a railgun using a sabot to launch a flyer plate for impacting an EOS target. Table 2 below lists representative results for 25- and 15-mm diameter, 1.5mm thick tantalum flyer plates, launched by 30- and 20-mm square bore, self-supporting sabots.

Table 2. Calculated Railgun Performance

Initial Stored Electrical Energy		20MJ		50MJ	
Velocity (Ta dia.)		v(25mm)	v(15mm)	v(25mm)	v(15mm)
Launcher Length	10m	17 mm/ μ s	25 mm/ μ s	19.5mm/ μ s	26.5mm/ μ s
	20m	20 mm/ μ s	31.5mm/ μ s	25 mm/ μ s	36 mm/ μ s
	40m	21.5mm/ μ s	37.5mm/ μ s	29.5mm/ μ s	46 mm/ μ s

We conclude that a 50 MJ stored electrical energy source (inductor, capacitor, etc.), together with a 20 m railgun barrel can be expected to launch a 15 mm diameter, sabot-supported tantalum disc to 37 mm/ μ s. The same result should be achievable with about half of the initial stored energy and twice the barrel length. The flyer plate would generate an extrapolated, single shock pressure of ~10 TPa upon impacting a tantalum target. Reflected and multiple shock techniques are also suitable for use with a railgun launched flyer plate. It appears that all EOS measurement techniques developed for light gas guns and explosively accelerated flyers, are applicable to the railgun.

1. S. C. Rashleigh and R. A. Marshall, J. of Appl. Phys.,
49, 2540, April 1978.
2. R. S. Hawke and J. K. Scudder, "Magnetic Propulsion
Railguns: Their Design and Capabilities," presented at
the Second International Conference on Megagauss
Magnetic Field Generation and Related Topics, May 29-
June 1, 1979, Washington, D.C., to be published. (Also
Lawrence Livermore Laboratory, Report UCRL-82677 (1979).

NOTICE

Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Department of Energy to the exclusion of others that may be suitable.

"This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights."