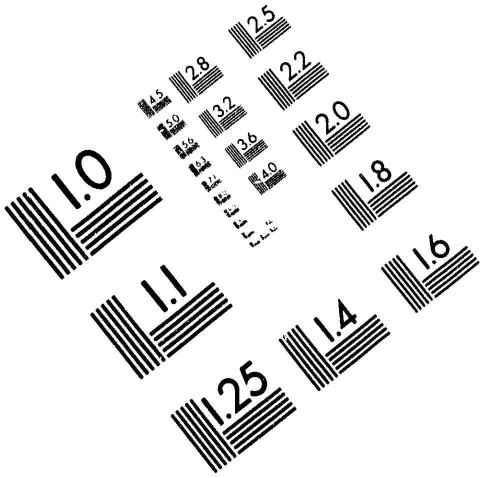
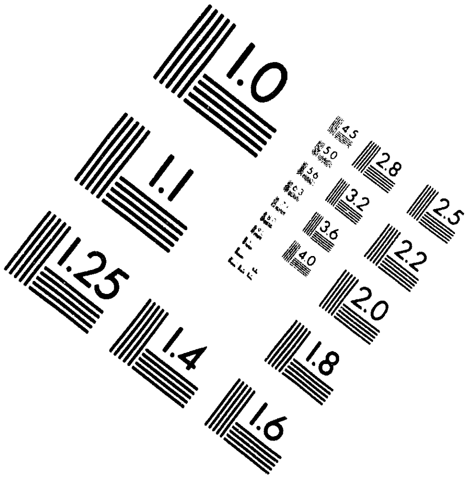
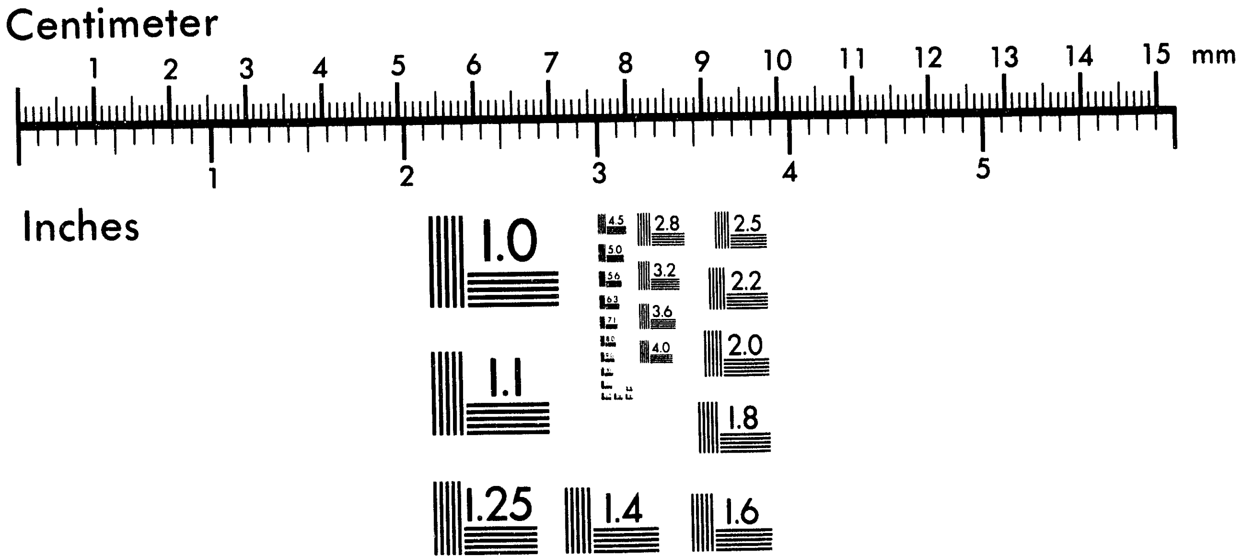


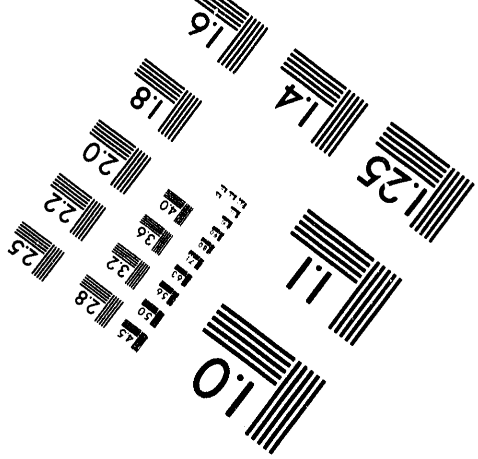
AIIM

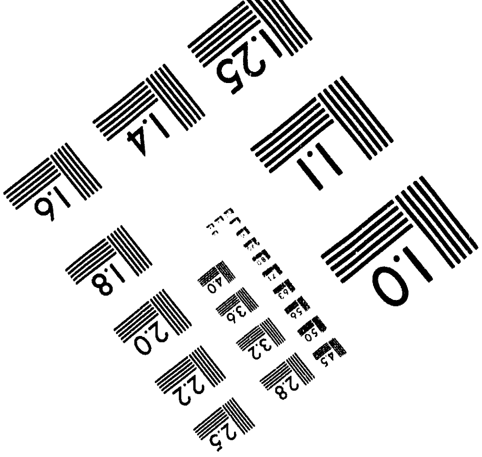
Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202









MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

SAND--94-2352C

Conf-940905--1

Recent Advances in the Development of High Average Power Induction Accelerators for Industrial and Environmental Applications

E. L. Neau

Sandia National Laboratories, MS1152,
PO Box 5800, Albuquerque, NM 87185-1152

ABSTRACT

Short-pulse accelerator technology developed during the early 1960's through the late 1980's is being extended to high average power systems capable of use in industrial and environmental applications. Processes requiring high dose levels and/or high volume throughput will require systems with beam power levels from several hundreds of kilowatts to megawatts. Beam accelerating potentials can range from less than 1 MeV to as much as 10 MeV depending on the type of beam, depth of penetration required, and the density of the product being treated. This paper addresses the present status of a family of high average power systems, with output beam power levels up to 200 kW, now in operation that use saturable core switches to achieve output pulse widths of 50 to 80 nanoseconds. Inductive adders and field emission cathodes are used to generate beams of electrons or x-rays at up to 2.5 MeV over areas of 1000 cm^2. Similar high average power technology is being used at ≤ 1 MeV to drive repetitive ion beam sources for treatment of material surfaces over 100's of cm^2.

KEYWORDS

Electron beam, ion beam, high average power, induction adder, magnetic switch

INTRODUCTION

Many applications of electron beam, ion beam, or x-ray processing have been described in the literature (Pikaev, 1994). These applications have developed around the availability of DC machines such as those from Radiation Dynamics Inc., Energy Sciences Inc., Nissan High Voltage, and others. Large, single-shot pulsed accelerators have also been developed over the last 30 years for applications such as the Inertial Confinement Fusion (ICF) program, flash x-ray sources for radiation effects studies, and for directed energy weapons programs. These accelerators exploit the benefits of short pulses to achieve high energy storage density and to achieve high accelerating potentials in new types of voltage adders. This paper will discuss work on a new family of pulsed accelerators based on experience with single-pulse machines, thermal management techniques (Wavrik, 1992), and refined saturable core switching (Neau, 1983) to deliver systems with high average power capabilities. Groups are developing repetitive, short-pulse high average power machines (Ashby, 1991; Goodman, 1992; Johnson, 1993) that are creating new opportunities in materials surface treatment, waste treatment, food processing, and other applications (Neau, 1994). Unlike thermal processes that heat a total product volume, high power short-pulse beams offer the efficient deposition of energy in a specific volume or in a well defined surface layer.

This work performed at Sandia National Laboratories is supported by the U.S. Department of Energy under contract DE-AC04-94AL85000.

87B

ACCELERATOR DEVELOPMENT

The need to develop a technology base to support a power plant design based on Inertial Confinement Fusion principles led to the formation of the Repetitive High Energy Pulsed Power (RHEPP) program at Sandia National Laboratories in late 1989. Articles (Harjes, 1990, 1992, 1993; Reed, 1990; Johnson, 1993) have described the initial design considerations and preliminary experiments with the RHEPP-I and RHEPP-II accelerators. These systems, at present powered by a 600 kW Westinghouse alternator, utilize magnetic switching, with 2605CO Metglas alloy cores, to form short-pulse outputs and employ linear induction voltage adder technology (Ramirez, 1985) using low-loss 2605-TCA Metglas isolation cores. MeV level outputs are formed from up to fifty, 250 kV input pulses, supplied by cables, from a single 0.88 ohm impedance water-filled, coaxial pulse forming line.

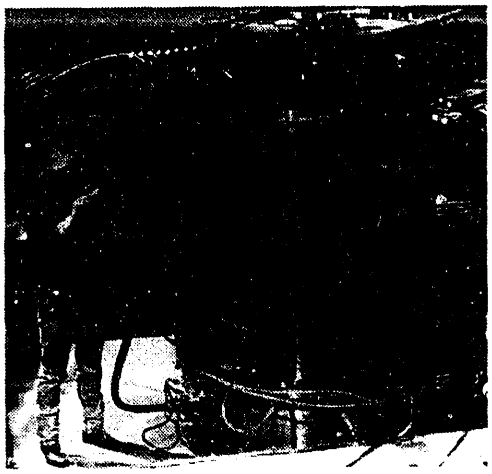


Fig. 1a - RHEPP-I 1 MeV accelerator,

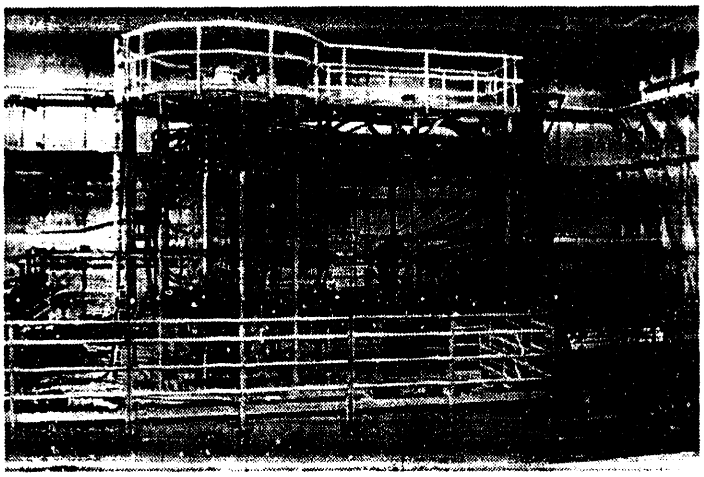


Fig. 1b - RHEPP-II 2.5 MeV accelerator

RHEPP-I (Fig. 1a) uses an oil insulated, four-stage voltage adder with a single conical vacuum interface to produce an output of 1 MeV and 50 kA into a matched 17.6 ohm load. Average power levels as high as 100 kW have been produced by 60 ns FWHM pulses at a 120 PPS repetition rate. This system is being used to drive pulsed, high current, ion beam sources for materials surface processing. RHEPP-II (Fig. 1b), in the commissioning phase, supplies 25 kA in a 60 ns FWHM output pulse to an 88 ohm electron beam load at an average power of approximately 200 kW. Output power will be increased to approximately 350 kW in the near future. This accelerator uses a vacuum insulated voltage adder with individual oil-vacuum insulators located in each oil-cooled isolation core assembly. Semiconductor switches, with a DC power supply and energy store, will replace one or more input magnetic switching stages for variable frequency accelerator operation. Experiments are planned with RHEPP-II to demonstrate the ability to kill pathogens in meat products, without adversely affecting product quality, while establishing a comparison with Cobalt-60 processing. RHEPP-II will also be used to investigate high speed ceramic brazing and composite joining.

APPLICATION DEVELOPMENT

Successful development of short-pulse high average power RHEPP technology depends on concurrent development of specific new applications that are enabled by the unique capabilities of this technology. Many application areas were identified (Fig. 2) at the onset of the RHEPP program that employ high power beams. A review identified the need to develop a modular technology base that can be extended to high accelerating potentials, or to high beam currents, while operating at high average power levels to cover different applications. Organic waste mitigation was investigated for a specific case that requires high dose and dose-rate levels while demonstrating the advantages of the short-pulse irradiation system. Figure 3 shows the total organic content mineralized about 3 times more effectively with the short pulse (40 ns) e-beam system as with the long pulse (40 ms) e-beam system (Patterson, 1993). The by-products of the mineralization process were not analyzed in these experiments.

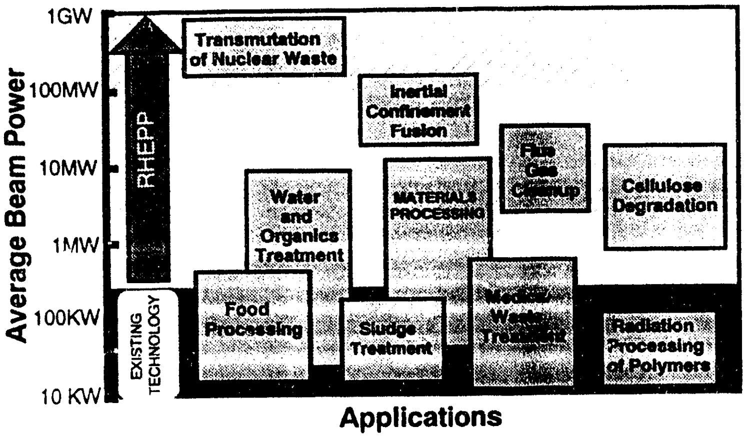


Fig. 2 Possible RHEPP technology application areas illustrate the need for average high power beams.

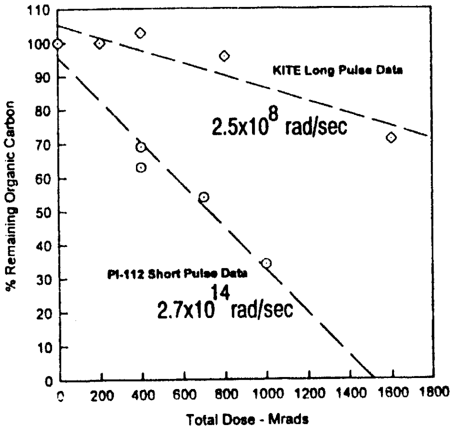


Fig. 3 E-beams can effectively destroy organic contaminants.

RHEPP high average power short-pulse technology can also furnish power to repetitive ion diodes (Greenly, 1988, 1990) for treatment of materials surfaces. Ions are extracted from an ionized gas plasma by the 60 to 80 ns applied accelerating pulse and are transported ballistically to the material surface in vacuum. The energy of the ion pulse is dissipated as heat in the top 2 to 10 microns of material surface depending on ion species and accelerating potential (Fig. 4). The material cools at a rate as high as 10^{10} °K/sec causing the formation of an amorphous surface layer and the production of nanocrystalline metastable phases. Figure 5 shows the carbide precipitates in tool steel dissolved and frozen in the rapidly resolidified layer extending an ion range into the top surface of the material.

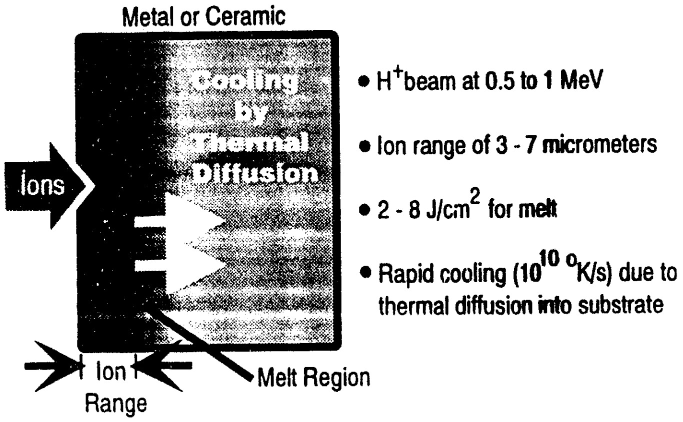


Fig. 4 Rapid melting and cooling are provided by 60 to 80 ns FWHM ion pulses.

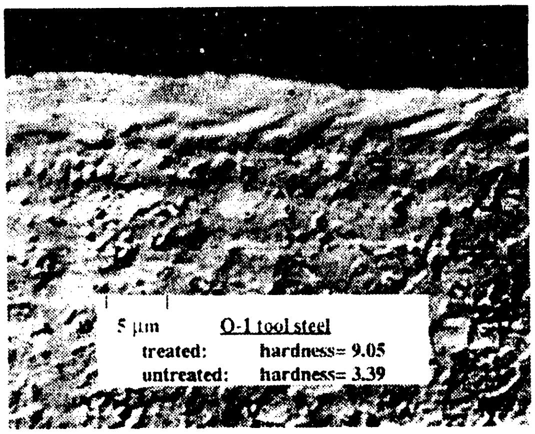


Fig. 5 Tool steel sample shows ion beam melt effects on top surface with improved surface hardness.

CONCLUSION

Short-pulse, high average power accelerator technology being developed for commercial applications is operational at the 100's of kW's of beam power with accelerating potentials of up to 2.5 MeV. Both electron and ion beams are being applied to new areas of industrial interest. Applications in materials surface processing and waste and pollution control are being developed to exploit the non-thermal conditions that can be created with short energy pulses from the new family of accelerators. Preliminary estimates; on the order of cents per square foot, cents per pound, and cents per gallon of processed material for high throughput applications indicate approximate cost increments for processed material. Continued development of long-life accelerator pulse compression components coupled with parallel development of high average power electron and ion beam sources are generating new and economical ways of addressing environmental and industrial manufacturing applications.

REFERENCES:

Ashby, S. et. al. (1991). CLIA - a compact linear induction accelerator. In: *Proc of the Eighth IEEE Int. Pulsed Power Conf.*, San Diego, CA, pp. 940-942

Goodman, D. L. (1992). High energy linear induction accelerators for material processing applications. In: *Proc. of the Radiational Technol. Int. Conf.*, Boston, MA, pp. 302-307.

Greenly, J. B. et. al. (1988). Magnetically insulated ion diode with a gas breakdown plasma anode. In: *J. of Appl. Physics, 63*, p. 1872

Greenly, J. B. et. al. (1990) Plasma anode ion diode research at Cornell. In: *Proc. of the Eighth Int. Conf. on High Power Particle Beams*, B. N. Breizman and B. A. Knyazev, Eds. Novosibirsk, p. 199.

Harjes, H. C. et. al. (1990). The repetitive high energy pulsed power module. In: *Proc. of the 1990 Nineteenth Power Modulator Symp.*, San Diego, CA, pp. 168-173.

Harjes, H. C. et. al. (1992). Initial results from the unipolar operation of the RHEPP module. In: *Proc. of the 1992 Twentieth Int'l Power Modulator Symp.*, Myrtle Beach, SC, pp. 83-.

Harjes, H. C. et. al. (1993). Characterization of the RHEPP 1µs magnetic pulse compression module. In: *Proc. of the Ninth IEEE Int'l pulsed Power Conf.*, Albuquerque, NM, pp. 787-790.

Johnson, D. L. et. al. (1993). Results of initial testing of the four Stage RHEPP accelerator. In: Proc. of the 9th IEEE Pulsed Power Conf., Albuquerque, NM, pp. 437-440.

Neau, E. L. (1983). COMET: A 6 MV, 400 kJ, magnetically-switched pulse-power module. In: *Proc of the 4th IEEE Pulsed Power Conf.*, Albuquerque, NM. pp. 246-250.

Neau, E. L. (1994). Environmental and industrial applications of pulsed power systems. *IEEE Trans on **Plasma Science***, **22**, No. 1, **pp.** 2-10

Patterson, E. L. et. al. (1993). Sandia National Laboratories Report SAND92-1969 • UC-602

Ramirez, J. J. et. al. (1985). The four stage HELIA experiment. In: *Proc. of the Fifth IEEE Pulsed Power Conf.*, Arlington, VA, pp. 143-146.

Reed, K. W. et. al. (1990). Channel cooling techniques for repetitively pulsed magnetic switches. In: *Proc. of the 1990 Nineteenth Power Modulator Symp.*, San Diego, Ca, pp. 192-199.

Wavrik, R. W. et. al. (1992). Thermal management in high average power pulsed compression systems. In: *Proc. of the 1992 Twentieth Int'l Power Modulator Symp.*, Myrtle Beach, SC, pp. 223-226.

Yatsui, K. (1989). Industrial applications of pulse power and particle beams. *Laser and Particle Beams*, 7, 733-741

DISCLAIMER

DATE
FILMED
10/13/94

END