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Two-Year Progress Report

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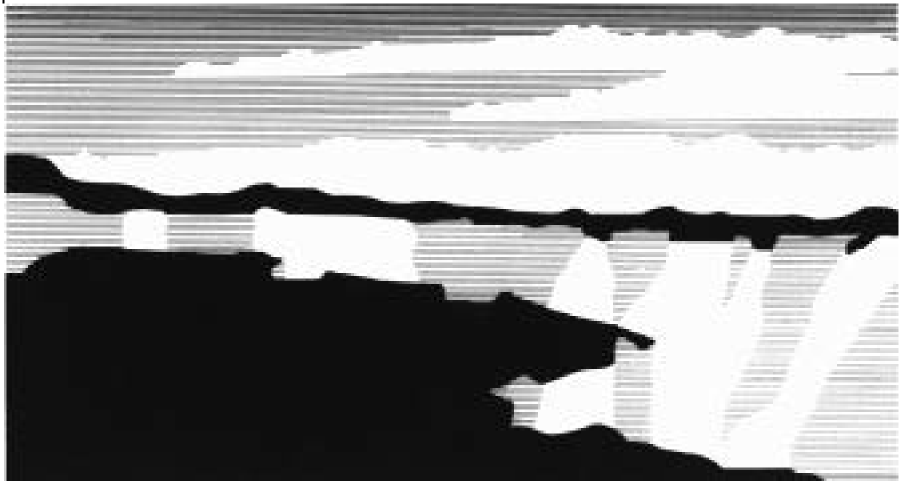

High Fluence Neutron Source for Nondestructive Characterization of Nuclear Materials. Project # 54751

Two-Year Progress Report

Mark M. Pickrell

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May 20, 1998

Research Objective

We are addressing the need to measure nuclear wastes, residues, and spent fuel in order to process these for final disposition. For example, TRU wastes destined for the WIPP must satisfy extensive characterization criteria outlined in the Waste Acceptance Criteria. Similar requirements exist for spent fuel and residues. At present, no nondestructive assay instrumentation is capable of satisfying all of the requirements. One of the primary methods for waste assay is by active neutron interrogation.

We plan to improve the capability of all active neutron systems by providing a higher intensity neutron source (by about a factor of 1,000) for essentially the same cost, power, and space requirements as existing systems.

This high intensity neutron source will be an electrostatically confined (IEC) plasma device. The IEC is a symmetric sphere that was originally developed in the 1950s as a possible fusion reactor. It operates as D-T neutron generator. Although it was not believed to scale to fusion reactor levels, these experiments demonstrated a neutron yield of 2×10^{10} neutrons/second on table-top experiments that could be powered from ordinary laboratory circuits (1 kilowatt). The basis for scaling the output up to 1×10^{11} n/s has been established. In addition, IEC devices have run for cumulative times approaching 10,000 hours. The essential features of the IEC plasma neutron source, compared to existing sources ***of the same cost, size and power consumption, are:*** neutron yield of 10^{11} compared to 10^{8}, lifetime of 10,000 hours compared to 500, and operation is pulsed or steady state compared to pulsed.

The design of a conventional IEC source is a spherical vacuum chamber containing a spherical grid. The grid is raised to a high negative potential. A breakdown develops between the chamber wall and the grid, and this plasma becomes a source of positive deuterium and tritium ions. These ions are accelerated to the center of the vacuum chamber sphere where they may collide. If the grid is raised to a nominal 100 kV, the coulomb barrier for D-T fusion, then the fusion cross section becomes quite large and the neutron production proceeds. The limiting factor has been high densities associated with the Paschen breakdown curve. Because of the high densities, the ions tend to collide multiple times before reaching the center and do not collide with the full accelerating potential. The Los Alamos IEC uses a triple grid design. In the triple grid IEC device, the inner grid is the accelerating grid and serves the same function as the single grid in conventional IEC systems. The central grid serves as electrical isolation, and is held at ground potential. The outer grid is raised to a modest positive potential, say 200 volts. Dispenser cathodes around the vacuum chamber wall inject electrons. The electrons are trapped and orbit around the outer grid, ionizing a local plasma. Because of the modest potential, the breakdown occurs at a different point on the Paschen curve, at a much lower density. The limit is further relaxed by the injected ionization from the dispenser cathodes. The result is a lower density plasma. The result is a tight focus of fully accelerated ions that collide in a beam-beam mode. The collision energy and neutron yield are large.

Research Progress and Implications

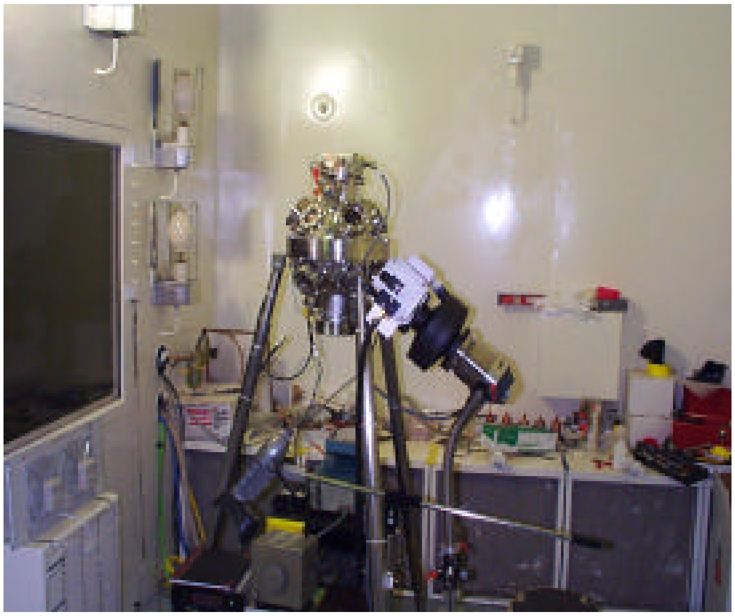
As of May, 1998, we have completed the construction of the IEC experiment, tested the initial plasma breakdown, and modified the experimental chamber. These activities were all part of the original experimental plan and are reflected in the milestone table below. A picture of the IEC experiment is shown below. The main effort so far has been the construction of the experimental facility. That work required the entire first year and larger funding than in subsequent years. The IEC experiment was completed on budget and ahead of schedule. The vacuum chamber, power supplies, gas system, vacuum system, and control electronics were all completed and tested.

This year the focus has been on initial plasma studies and plasma breakdown. The key to the IEC experiment is the breakdown conditions. The object is to achieve breakdown at lower densities so that the plasma is less collisional and the accelerated ions travel all the way to the center before colliding. Therefore, we have experimented with the vacuum chamber design in order to achieve the low density breakdown. As a result of these studies, the high voltage grid design and the electron injector design were modified. These changes were made to optimize the neutron performance.

The Los Alamos IEC design is significant. IEC research has been conducted for over 3 decades, but always with a single grid. All previous attempts have suffered from high density, marginal neutron output, and limited lifetime because of neutral particle sputtering. All of these effects are due to the high plasma density. The Los Alamos design has already shown it can achieve lower densities. What remains is to operate the device at high voltage and maintain the low densities. During these operations we will also measure neutron yield in deuterium, which is a factor of 100 lower than for the D-T mix. We intend to optimize performance in deuterium to achieve 10^9 n/s, which is equivalent to the goal of 10^{11} n/s in D-T

Planned Activities

We plan to continue the research program that was originally outlined in our proposal. The revised plasma chamber is complete. Our next step is to begin producing neutrons in a D-D environment and optimize neutron production and system lifetime. Once we have fully optimized output from D-D (hopefully to the level of 10^9 neutrons / second), we will seal the vacuum chamber and attempt to run with tritium and achieve the goal of 10^{11} n/s. Once we have defined the physics and operating parameters, we will re-engineer the system with a commercial partner in order to make this a commercial product that can be used in a wide range of nondestructive assay (NDA) systems. Having a commercially-available system is crucial to the deployment of this technology as well as the incorporation of it into future NDA systems. Our schedule of milestones is shown below; a picture of the system is shown to the right.



Milestone	Date	Accomplishment	Status
1	4 mos	Procure all power supplies and vacuum equipment.	Done on time.
2	8 mos	Execute CRADA agreement	Postponed.
3	8 mos	Complete construction of electrical systems.	Done on time.
4	10 mos	Build vacuum chamber	Done on time.
5	11 mos	Initiate experimental program	Done on time.
6	16 mos	Complete initial experimental program.	Done.
7	20 mos	Build second vacuum chamber.	Done.
8	26 mos	Complete second experimental program.	
9	30 mos	Complete industrial engineering design.	
10	32 mos	Complete technology transfer.	

Information Access

The following bibliography lists the papers presented on this research project and related work:

1. R. A. Nebel, D. C. Barnes, “The Periodically Oscillating Plasma Sphere”, to appear in Fusion Technology, August (1998).
2. D. C. Barnes, R. A. Nebel, “Stable, Thermal Equilibrium. Large-Amplitude, Spherical Plasma Oscillations In Electrostatic Confinement Devices”, to appear in Physics of Plasmas, July (1998).
3. R. A. Nebel, D. C. Barnes, R. Bollman, G. Eden, L. Morrison, M. M. Pickrell, W. Reass, “The Los Alamos Intense Neutron Source”, to appear in the Proceedings of 2nd Symposium on CURRENT TRENDS IN INTERNATIONAL FUSION RESEARCH: REVIEW AND ASSESSMENT, Washington, DC March 1997.
4. R. A. Nebel, D. C. Barnes, “The Periodically Oscillating Plasma Sphere”, paper 1B-3 presented at 1997 Sherwood Theory Meeting, Madison, WI April 1997 (invited paper).
5. D. C. Barnes, R. A. Nebel, M. M. Schauer, and M. M. Pickrell, “Inertial Electro-Magnetostatic Plasma Neutron Sources”, Paper 7E04, 1997 IEEE International Conference on Plasma Science, May 19-22, 1997, San Diego, CA, p. 319 (invited paper).
6. R. A. Nebel, et. al., “The Los Alamos Intense Neutron Source”, Winter ANS meeting, Albuquerque, NM (1997) (invited paper).
7. R. A. Nebel, D. C. Barnes, R. Bollman, G. Eden, L. Morrison, M. M. Pickrell, W. Reass, B. P. Bromley, L. Chacon, “The Los Alamos Intense Neutron Source”, paper kWeaP1 5, Bull. Am. Phys. Soc., 42, 1955 (1997).
8. R. A. Nebel, D. C. Barnes, “The Los Alamos Intense Neutron Source and the Periodically Oscillating Plasma Sphere”, paper 3C22 1998 Sherwood Theory Meeting, Atlanta, Ga. 1998.
9. R. A. Nebel, D. C. Barnes, R. Bollman, G. Eden, L. Morrison, M. M. Pickrell, W. Reass, M. M. Schauer, K. R. Umstadter, “The Los Alamos Intense Neutron Source and the Penning Fusion Experiment”, Proc. IAEA Meeting on Innovative Approaches to Fusion Energy, Pleasanton, Ca., (1997).