FSL Report 526

**DEVELOPMENT of a
NOVEL NEUTRON SOURCE with
APPLICATIONS in
CALIBRATION and MONITORING**

Prepared by
George H. Miley

**Fusion Studies Laboratory • Dept of Nuclear Engineering
University of Illinois at Urbana-Champaign
Urbana, IL 61801-2984**

April 1995

DISCLAIMER

**Final Report
Contract DEFG02-93ER75873**

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of 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. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Prepared for
U.S. Department of Energy

MASTER

Original
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED *MS*

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DEVELOPMENT of a NOVEL NEUTRON SOURCE with APPLICATIONS in CALIBRATION and MONITORING

Table of Contents

I.	Introduction	1
II.	Novel IEC Application Studies	1
III.	Student Participation	2
IV.	Conclusion	2
V.	References	3
<i>Removed</i> Appendix A.	Abstract and Table of Contents from Annual Report	4
<i>Removed</i> Appendix B.	"Conceptual Design for a D- ³ He IEC Plant"	6
<i>Removed</i> Appendix C.	"Innovative Technology for an Inertial Electrostatic Confinement (IEC) Fusion Propulsion Unit"	10
<i>Removed</i> Appendix D.	"The IEC: A Novel Source for Boron Neutron Capture Therapy"	16
<i>Removed</i> Appendix E.	"A Conceptual Design for a BNCT Facility Using an IEC Fusion Source"	28
<i>Removed</i> Appendix F.	Brief Publications List, 1994-95	30

DEVELOPMENT of a NOVEL NEUTRON SOURCE with APPLICATIONS in CALIBRATION and MONITORING

I. Introduction

The objective of this research project, development of a unique portable inertial electrostatic confinement (IEC) neutron source (10^6 2.5-MeV neutrons/second-level) has been achieved. A majority of the experimental work required for the project was reported in the 1993 Annual Report.¹ (The abstract and table of contents for that report are included here as *Appendix A* for convenience. Full copies can be obtained upon request to the PI.) Unfortunately, the DOE program providing support for the project was canceled and funding was not available to continue the project in 1994-95. However, to provide time to explore some innovative potential applications for upgraded versions of the IEC, a no-cost extension of the contract was requested and granted in 1994. This follow-on work, mostly involving conceptual design studies, is reported here.

II. Novel IEC Application Studies

Conceptual design studies were carried out for several potential applications of an upgraded IEC device. The first of these, concerning a D-³He-fueled fusion power unit, was presented at the *Seventh International Conference on Emerging Nuclear Energy Systems*.² The resulting paper from that work was published in the conference proceedings in 1994, and is included as *Appendix B*. In 1994, the use of a modified version of this power unit for fusion space propulsion was presented at the *11th Symposium on Space Nuclear Power and Propulsion*,³ and the symposium paper is included as *Appendix C*.

In both cases, the compactness and high power density of the IEC would offer an extremely high power/weight energy-producing unit with relatively insignificant radioactivity handling and disposal concerns. Low-level radioactivity would arise from some activation of structural components by neutrons from associated D-D reactions in the D-³He mixture, and the production of small amounts of tritium from these reactions. This radioactivity would be several orders of magnitude less than that for a "conventional" D-T fusion plant, however. Further, due to the non-Maxwellian beam-beam-type fusion and the absence of a magnetic field, the IEC is uniquely suited to efficient burning of advanced fuels, such as D-³He. A "best" source of ³He remains an open issue. Options include lunar mining and production in D-D breeder reactors. For near-term experiments and limited operation, there is an adequate supply of ³He from tritium decay associated with the nuclear weapons program.

The second potential application of an upgraded IEC is using it as a high-yield neutron source for boron neutron capture therapy (BNCT), a human cancer treatment method. Papers on this topic, presented at the *First International Workshop on Accelerator-Based Neutron Sources for Boron Neutron Capture Therapy*,⁴ and at the *American Nuclear Society Annual Meeting*.⁵ These papers are included as *Appendix D* and *E*, respectively. As explained in these papers, the combination of compact size, relatively low cost, and monoenergetic neutron emission without gamma contamination makes this concept a leading candidate for installation in clinics and hospitals (vs. a large, centralized facility employing a nuclear reactor source). The paper in *Appendix E*, in particular, considers the design of a hospital facility utilizing the IEC source.

A listing of additional publications for the period 1994-95 is included in *Appendix F*.

III. Student Participation

A number of graduate students in Nuclear Engineering (NE) and Electrical and Computer Engineering (ECE) have been partially supported by this project. These include:

- Y.B. Gu, Ph.D. candidate in ECE
- A.J. Satsangi, M.S. candidate in NE
- P.F. Heck, M.S. candidate in NE
- I.V. Tzonev, M.S. candidate in NE
- B.P. Bromley, M.S. candidate in NE
- J.M. DeMora, M.S. candidate in NE

Thus the project was not only successful technically, but it has also made an important contribution to student engineering education by providing both financial support and a challenging, exciting research opportunity.

IV. Conclusion

The IEC development supported by this project has been very successful. Funding for an improved version of the basic unit was not obtained due to cancellation of the sponsoring DOE program. Still, considerable insight into the potential for IEC applications has been obtained through the various conceptual design studies described here. These include use as a compact D-³He power plant for both terrestrial and space applications and as a neutron source for medical applications such as BNCT.

V. References

1. G.H. Miley and J.B. Javedani, "Development of a Novel Neutron Source with Applications in Calibration and Monitoring," FSL-467, Fusion Studies Laboratory, U. of Illinois (1993).
2. G.H. Miley, A. Satsangi, J. Javedani, and Y. Yamamoto, "A Gridded D-³He IEC Power Plant," Seventh Intern. Conf. on Emerging Nucl. Energy Systems (ICENES '93), ed. H. Yasuda, World Scientific, Singapore, 66-70 (1994).
3. A.J. Satsangi, G.H. Miley, J.B. Javedani, H. Nakashima, and Y. Yamamoto, "Innovative Technology for an Inertial Electrostatic Confinement (IEC) Fusion Propulsion Unit," Proceedings of the 11th Symposium on Space Nuclear Power and Propulsion, Conf 940101, AIP Press, 1297-1302 (1994).
4. G.H. Miley, et al., "The IEC: A Novel Source for Boron Neutron Capture Therapy," First Intern. Workshop on Accelerator-Based Neutron Sources for Boron Neutron Capture Therapy, INEL Conf-940976, 79-88 (1995).
5. J.M. DeMora, G.H. Miley, et al., "A Conceptual Design for a BNCT Facility Using an IEC Fusion Device," FSL #515, accepted for presentation, *American Nuclear Society Annual Meeting*, 23-29 June 1995, Philadelphia, PA.