00
7-74
ANCR-1176

Dr-1044
UC-20

POSSIBILITIES OF NEUTRON SOURCES
AT NRTS FOR CTR MATERIALS TESTING

R. M. Brugger

Aerojet Nuclear Company

NATIONAL REACTOR TESTING STATION

Idaho Falls, Idaho — 83401

MASTER

DATE PUBLISHED—AUGUST 1974

PREPARED FOR THE

U. S. ATOMIC ENERGY COMMISSION

IDAHO OPERATIONS OFFICE UNDER CONTRACT AT(10-1)-1375

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

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.

DISCLAIMER

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

Printed in the United States of America
Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy \$4.00; Microfiche \$1.45

LEGAL NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, 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.

ANCR-1176

Controlled Thermonuclear Processes
and Plasma Physics
TID-4500

POSSIBILITIES OF NEUTRON SOURCES AT NRTS
FOR
CTR MATERIALS TESTING

R. M. Brugger

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, 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.

AEROJET NUCLEAR COMPANY

Date Published -- August 1974

PREPARED FOR THE U. S. ATOMIC ENERGY COMMISSION
IDAHO OPERATIONS OFFICE
UNDER CONTRACT NO. AT(10-1)-1375

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED
K/B

ABSTRACT

This document is one of several descriptions how the NRTS has contributed to the USA's fission reactor development program and how the NRTS can contribute to the USA's fusion reactor development program. This document describes neutron sources that can be used for materials damage studies of CTR materials and how these can be developed and applied at the NRTS. The first section briefly outlines the need for such sources in the fusion program. The second section describes how the NRTS was the nation's center for radiation sources used for materials damage studies for all types of fission reactors. The third section suggests CTR radiation sources and how these would fit into facilities at the NRTS.

CONTENTS

ABSTRACT	ii
INTRODUCTION	1
Materials Damage Experience at the NRTS for Fission Reactors .	4
Suggestions of NRTS Support to CTR Programs	6
A. Gas Target Development	6
B. Heavy Ion Acceleration	6
C. Plasma Focus	8
D. FERF	10
REFERENCES	14

FIGURES

1. Artist's concept of tritium accelerator and deuterium gas target at CF-633	7
2. Artist's concept of a plasma focus device at TAN-607	9
3. Concept of a mobile mirror focus machine	11
4. Concept of mobile mirror focus machine in LOFT Facility Containment Building	12
5. Concept of radioactive reactor (shown in Fig. 3) in large hot cell at TAN-607 for refitting or dismantling	13

TABLE

I. Possible Approaches to 14 MeV Neutron Source	2
---	---

POSSIBILITIES OF NEUTRON SOURCES AT NRTS
FOR
CTR MATERIALS TESTING

R. M. Brugger

INTRODUCTION

The need for materials testing and development has been identified as the second most critical item in the CTR program; achieving break-even and net energy production is the first. This materials testing is dependent on achieving a materials testing reactor (as was achieved in thermal fission reactor development with the operation of the MTR) which will provide a flux of radiation representative of a CTR reactor and of high enough intensity to produce the damage of an operating CTR reactor but in $\sim 1/10$ the time. No such testing facility is now available. Persiani has evaluated, for the DCTR, the need for radiation testing facilities, the neutron sources presently available and possible future neutron sources. Some of Persiani's charts are reproduced in Table I for reference.

The DCTR has recognized the need for research, development, engineering, and operation of radiation test facilities and concludes that through timely research, sources will be achieved. The Division has identified such facilities as PTNS (Plasma Target Neutron Source) and FERF (Fusion Engineering Research Facility) in their program plan.

A CTR power reactor will produce primary damaging radiation of 14 MeV and/or 2.5 MeV neutrons, x-rays and gamma rays, charged particles of α 's, ^3He , t, d, p and fusion fuel debris. The neutron fluxes

TABLE I

POSSIBLE APPROACHES TO 14 MeV NEUTRON SOURCE⁽¹⁾

TYPE	NEUTRON INTENSITY	COMMENTS	PARAMETERS	RELATION TO SFX	TIME SCALE	PHYSICS EXTRAPOLATIONS	ENGINEERING EXTRAPOLATIONS	COST
MIRROR	5×10^{14} (n/cm ² /sec)	NEUTRAL INJECTION	10MW; 75keV; 130A; 40KG 3 to 1 MIRROR 24 LITERS $nt \sim 7 \times 10^{12}$	10-100 BELOW SFX	POSSIBLY BEFORE SFX.	BEAM-PLASMA INTERACTION $\frac{nt}{nt_{classical}} = ?$	LARGE BEAMS & MAGNETS OF NbTi	\$50 M
e PINCH	3×10^{12} (n/cm ² /sec)	180 M TOROIDAL OR 1000M LINEAR	$\frac{1}{2}$ cps, $T_i =$ 8KeV; 80 KG; $r=3cm$; $n =$ 8×10^{15}	IT IS SFX BUT FASTER PULSE RATE	1982	STAGING, CONFINEMENT	SUPERCONDUCTING ENERGY STORAGE & SWITCHING	\$50 M
LASER SOLENOID	3×10^{12} (n/cm ² /sec)	14 M LINEAR NEAR STATE-OF- ART 50 KJ LASER	10 cps, $n_e = 10^{18}$; $T_e = 3KeV$; 500 KG @ 1 CM BORE; $r=1mm$; $nt = 3 \times 10^{13}$	10 to 100 BELOW SFX	1976	SELF-FOCUSING ANOMALOUS EFFECTS	LASER & MAGNET (BOTH NEAR STATE OF ART)	\$15 M
E BEAM HEATING	$10^{14} - 10^{15}$ (n/cm ² /sec)	ASSUME E ENERGY GOES TO T_i	1 cps; $T_i = 10keV$ 50 - 500 kW/LITER 60 - 200 KG $n=10^{16} - 10^{17}/cm^3$ 10 - 100 usec	10 to 100 BELOW SFX	1978	CONTAINMENT TIME; ION ENERGY TRANSFER	1 PULSE PER SEC DEVICE (SINGLE SHOT)	\$8 M
HIGH DENSITY PINCH	1×10^{14} (n/cm ² /sec)	1 M LINER DRIVEN, @ PINCH CUSP	1 cps, 3 MG; 10KeV; $n=10^{19}$ 200 MJ @ PINCH 30 MJ CUSP	IT IS SFX BUT FASTER PULSE	1978	FLUID DYNAMICS OF LINERS	INDUCTIVE STORAGE & SWITCHING	\$50 M
GAS TARGET	4×10^{14} (n/cm ² /sec)	INTERSECTING T-D BEAMS	1.5A OF T AT 270KeV; 1 cc Vol; 4×10^{19} D TARGET	NONE	1980	JET NOZZLE AERODYNAMICS	NOZZLE & BEAM TRANSPORT DESIGN	\$1 M R&D \$5 M FACIL.
LASER OR E.B.- PELLET	10^{16} (n/pulse)	---	~ 1 pps	IT IS SFX BUT FASTER PULSE RATE	---	---	---	---
PLASMA FOCUS	10^{15} (n/pulse)	1 MJ BANK	~ 1 pps.	NONE		STATE-OF-ART EXCEPT FOR REPETITION RATE		\$5M PER MJ

- NOTES: 1) Tentative conclusions reached at informal experts meeting held at AEC Headquarters, Germantown, Md. on December 5, 1972.
 2) All Sources Require T Handling & Pose Materials Damage Problems Not Present In SFX.
 3) T Handling Not Included In Cost Guesses Except For Gas Target.
 4) \$10 to \$20 Extra To Up The Rep. Rate For Some Of The Above.
 5) Tokamaks Not Considered As A Reasonable Approach.
 6) 40 MWe Gas Turbine Power Supply Would Cost Approximately \$4M.

TABLE I (contd.)
14 MeV Neutron Source Development

<u>Activity</u>	<u>Completion, FY</u>
Assess Possible Approaches (1/2 year)	1973
Preliminary Source Design (1 year)	1974
Supporting Research and Development (2 years)	1976
Final Design & Construction (Titles I-IV, 3 years)	1979
Initial Operation and Debugging (1 year)	1980
Irradiate Selected Materials & Systems (4 years)	1984
Feedback - Continuous	----
Testing of New Materials and Systems (4 years)	1988
Data Assembly for Experimental Reactor Design (1 year)	1989

(Construction start for Mark II model about 1981 is likely)

at the first wall will be as high as 10^{14} n/cm²/sec and fluences of 10^{22} n/cm². Since many of the possible energy producing CTR reactors will be pulsed, the materials testing facility should operate steady-state and/or pulsed with bursts as short as 10^{-9} sec. The best source that now exists provides steady fluxes of 14 MeV neutrons of $\sim 10^{12}$ n/cm²/sec over a small sample area. While there is confidence that a materials testing source will be developed, there is need for extensive research and development to achieve a viable neutron source for CTR materials damage studies. It also appears that such sources will be large facilities and the optimum cost effective facility and site needs to be identified.

Materials Damage Experience at the NRTS for Fission Reactors

The NRTS can fulfill a parallel function in CTR materials damage as it has in radiation damage for fission reactors. The NRTS was established in 1949 as a test site for fission reactors and the second reactor (of more than 50) to go critical at the site was the nation's Materials Testing Reactor to provide very high fluxes and fluences of neutrons that characterize the flux in thermal fission reactors. The MTR achieved the X10 greater fluxes than were to be experienced in thermal power reactors, so that exposure experience could be accelerated and damage studied before power plant designs were finalized.

The NRTS has been the center of the U.S. program of materials testing facilities for fission reactors. Most types of fuel, structural material and shielding have been tested under a diversity of conditions. For example, the Experimental Breeder Reactor No. II is the nation's only operating fast reactor (at more than zero power) and is now

carrying the load of fuel and materials testing for fast reactor systems at high steady fluxes of neutrons characteristic of the fast spectra encountered in fast fission reactors. The TREAT facility is designed to expose fuel to extreme transients and is used to determine materials properties of fast reactor fuels under these extreme conditions.

The triumvirate of thermal materials testing reactors, the MTR, ETR, and ATR, were designed and operated to expose thermal reactor fuel and structural material to extreme fluences of thermal neutrons. These have provided the backbone of materials testing for the Navy reactor development program, the aircraft nuclear propulsion program and the development of all the LWR power reactor development programs including the LWBR.

Testing of thermal reactor fuel in extreme transient conditions has been pursued in the Spert reactors, and will be advanced in the PBF and LOFT facilities. LMFBR, HTGR and HTBR fuels will also be tested in PBF and ETR.

Besides the properties of fuels, the materials properties of a variety of coolants have been tested at the NRTS. The OMRE and EOCR were used to evaluate organic coolants under irradiation. The MTR-ETR-ATR are used to evaluate the chemistry of coolants, such as water, under radiation conditions while EBR-II evaluates the properties of Na as a coolant.

From this diversity of experience, one sees that the NRTS is the nation's major materials testing site for fission reactors, that the NRTS has shown the capability to conceive, design, construct and operate materials testing facilities besides conceiving and conducting the experimental programs.

Suggestions of NRTS Support to CTR Programs

While the NRTS has been heavily involved in the nation's program of materials testing for fission reactors, there have been no programs at the NRTS for fusion. However, the NRTS can and should serve the CTR programs for materials testing as it has served the fission development program of the nation carrying over the technical, engineering, construction, operating, and management skills that have supported the fission program of the AEC (2,3). Below are a few suggested modes by which the NRTS could effectively participate in the materials testing area.

A. Gas Target Development - 14 MeV neutron sources proposed by LASL and Westinghouse suggest supersonic jet gas targets to solve the problem of energy removal from the target bombarded by a high current. Such accelerator neutron sources could be built into the unused facilities at the NRTS thus saving the cost of buildings. Figure 1 is an artist's concept of how a tritium accelerator and deuterium gas target system might fit into the CF-633 building.

B. Heavy Ion Acceleration - There is interest in the use of heavy ions, both as an accelerator plus target arrangement for producing 14 MeV neutrons and as a method of imploding fusion pellets and fission pellets. In both cases, lower energies but higher particle currents than requested by the "heavy ion" researchers are required. Energies between 0.4 and 40 MeV of single charged ions up to uranium will be required at currents up to amps. If such currents bombard a mixture of D+T, 14 MeV neutrons are produced by a chain reaction.

If heavy ions (instead of tritons into deuterium), are accelerated

Fig. 1 Artist's concept of tritium accelerator and deuterium gas target at CF-633.

into a DT gas target another degree of freedom is introduced into the design. The thermal diffusion isotope separators from a PTNS could be eliminated and one can consider direct pumping of the gas target with the heavy ion beam thus eliminating the gas pumps also. The researchers at the NRTS could evaluate and develop this method.

At present much emphasis is focused on efforts to implode DT pellets (and a little interest in imploding fission pellets) with lasers and electron beams. It appears that heavy ions also have potential for such implosions and might provide the key to achieving break-even. Once again these ion beams of heavy ions are at lesser energy but higher current than desired by the "heavy ion" researchers.

The NRTS, with its facilities and research staff, could help the AEC in the area of developing heavy ion beams for both 14 MeV neutron sources and for pellet implosion.

C. Plasma Focus - Recent measurements with plasma focus machines indicate that these may be the devices to first achieve 10^{15} n/sec plus simulate the "plasma wind". Aerojet General Company had an extensive program developing plasma focus devices. This program, which was funded by the Air Force, was terminated in 1967 but the core of this effort is now at Lawrence Livermore Laboratory conducting similar experiments and proposing future devices that should achieve the 10^{15} n/sec desired. With the renewed promise of the plasma focus and the proposal for a larger device, the AEC should consider placing it at a national test station and capitalize on isolation and control of area. Figure 2 is an artist's concept of how such a plasma focus device might fit into the drained shielded pool at the TAN-607 building at the NRTS.

Fig. 2 Artist's concept of a plasma focus device at TAN-607.

D. FERF - The DCTR has identified the need for a large radiation source, called FERG, for materials testing. Such a source could be located at the NRTS to use the existing facilities and capabilities. Figure 3 is an artist's concept of a mirror focus machine as such a source but built on a rail car as were the HETR nuclear aircraft engines and as is the LOFT reactor. This could be assembled in the south bay of the TAN-607, then rolled to the containment vessel as shown in Figure 4. After operation, the radioactive reactor could be rolled to the large hot cell of TAN-607 to be refitted for reuse or dismantled as shown in Figure 5.

Fig. 3 Concept of a mobile mirror focus machine.

Fig. 4 Concept of mobile mirror focus machine in LOFT Facility Containment Building.

Fig. 5 Concept of radioactive reactor (shown in Fig. 3) in large hot cell at TAN-607 for refitting or dismantling.

REFERENCES

1. P. J. Persiani, "Preliminary CTR Neutron Source Considerations", Argonne National Laboratory, (1972).
2. ANCR-1134 - "Fission Fragment Driven (d+t) Neutron Irradiation Source for CTR Materials Damage Irradiations", L. G. Miller, R. C. Young, R. M. Brugger, January 1974. (Patent Idea ANC-PI-19, "Fission Fragment Driven (d+t) Neutron Irradiation Source for CTR Materials Damage Irradiations").
3. ANCR-1154 - "Production of 14 MeV Neutrons by Heavy Ions", R. M. Brugger, R. C. Young, and L. G. Miller, May 1974. (Patent Idea ANC-PI-21, "Production of 14 MeV Neutrons by Heavy Ions").