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.

MASTER

COO-2250-35

Distribution

MIT LMFBF Blanket Research Project
Quarterly Progress Report

Department of Energy Research and Development
Contract EY-76-S-02-2250
UC-79P LMFBF-Physics

- 1-3 U.S. Department of Energy
Division of Reactor Development and Technology
Reactor Physics Branch
Washington, D.C. 20545
- 4-9 Harold N. Miller, Director
Contract Management Office
U.S. Department of Energy
9800 South Cass Avenue
Argonne, Illinois. 60439
- 10 Director, Nuclear Power
Electric Power Research Institute
Post Office Box 10412
Palo Alto, California 94303
- 11 c/o Ms. G. L. Ehrman
School of Nuclear Engineering
Purdue University
West Lafayette, Indiana 47907

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

EHR

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.

COO-2250-35

MIT LMFBR BLANKET RESEARCH PROJECT

Quarterly Progress Report
October 1, 1978 - December 31, 1978

Principal Investigator
Michael J. Driscoll

Massachusetts Institute of Technology
Department of Nuclear Engineering
Cambridge, Massachusetts 02139

February 15, 1979

Prepared for the U.S. Department of Energy under Contract No.
EY-76-S-02-2250

1. General

The project's engineering assistant, A. T. Supple, has transferred to another research group at MIT. Arrangements have been made to utilize MIT Reactor support personnel to maintain our experimental capability and to help conduct such experimental runs as may be called for.

Arrangements are in progress to return to DOE all fuel rods excess to current and projected needs.

As general information of interest, it should be noted that two closely related projects have recently been funded at MIT:

- (a) An evaluation, for GA, of the use of internal blankets in the GCFR. A thesis prospectus by the student involved, Dale Lancaster, is appended.
- (b) An evaluation, for BNL, of the Fast Mixed Spectrum Reactor. A thesis prospectus by the cognizant student, Wee Tee Loh, is also appended.

These projects will be closely coordinated with our Blanket Project Research to avoid duplication of effort.

This report summarizes work completed, in progress, or planned since our last quarterly report: MIT LMFBR Blanket Research Project, Quarterly Progress Report, July 1, 1978 - September 30, 1978, COO-2250-34.

2. Interface Self-Shielding

An explanation has been advanced as to why, relatively speaking, we have seen in our experiments such a large excess in resonance absorptions near thorium/uranium interfaces in axial traverses, but a much smaller effect near the blanket/reflector interface in the "radial" direction. The difference is attributed to the existence of a steep ($\sim$ exponential) flux (hence capture) gradient in the latter case as opposed to the nearly flat flux in the former instance (measurements near the Q_1 of a cosine-shape flux). In the calculations ∞ -medium Dancoff factors have been used. Since shadowed-neutrons form a "source of negative neutrons" which do not reach the interface fuel, we can examine the consequences of this treatment.

The deficit in shadowed neutrons not reaching the surface of a half space containing an exponentially varying spatial source is:

$$\begin{aligned}
 S &= \frac{1}{2} \int_0^{\infty} e^{\alpha x} dx \int_0^1 e^{-\frac{x}{\lambda \mu}} d\mu \\
 &= \frac{-1}{2\alpha^2 \lambda} [\ln(1-\alpha\lambda) - \alpha\lambda] \\
 &\approx \frac{\lambda}{4} [1 + 2/3 \alpha\lambda + \dots]
 \end{aligned}$$

If the flux is flat ($\alpha = 0$), $S = \lambda/4$, a well-known result; hence in an infinite medium (two contiguous half-spaces) $S = \lambda/2$.

If the exponential source continues into the other half space, its contribution is determined by replacing α by $-\alpha$ in the preceding derivation, to obtain:

$$\begin{aligned}
 S &= \frac{1}{2\alpha^2 \lambda} [\alpha\lambda - \ln(1+\alpha\lambda)] \\
 S &\approx \frac{\lambda}{4} [1 - 2/3 \alpha\lambda + \dots]
 \end{aligned}$$

Thus the sum of the left and right half spaces, is to first approximation, $S = \lambda/2$ even in a flux gradient. We conclude that deep inside a region the flat-flux, ∞ -medium Dancoff treatment is adequate regardless of flux shape.

Furthermore, in a radial blanket, with a steep flux gradient ($2/3 \alpha \lambda \approx 1$), the shadowing will also be proportional to $S \approx \lambda/2$ near the blanket/reflector interface; or in other words, use of infinite medium, flat-flux Dancoff factors may fortuitously give a nearly correct result. On the other hand, in an internal blanket, with the surrounding flux being rather flat, $S \approx \lambda/4$ at an interface, and use of infinite medium Dancoff factors will underestimate the resonance absorption at the interface.

Our current thinking is that we may be able to use the above approach to define appropriate unit cells which would allow standard programs such as SPHINX to general interface-region cross section sets in a convenient manner.

A topical report in this area is being drafted by M. Saidi. The attached table of contents constitutes a preliminary version of the material to be covered.

"Interfacial Effects In Fast Reactors"

Projected Table of Contents

- Chapter 1. Introduction
 - 1.1 Foreword
 - 1.2 Background
 - 1.3 Scope of This Report
- Chapter 2. Design and Construction of the Interface Traversing Subassembly (ITS)
 - 2.1 Introduction
 - 2.2 Blanket Test Facility Structure
 - 2.3 Design of the I.T.S.
 - 2.3.1 The purpose of the design
 - 2.3.2 ANISN Calculations
 - 2.3.3 2DB Calculations
 - 2.3.4 Final Design of ITS
 - 2.4 Construction of ITS
 - 2.5 Summary
- Chapter 3. ITS Experiments
 - 3.1 Introduction
 - 3.2 Experimental Procedures
 - 3.2.1 Description of Foil Materials
 - 3.2.2 Experimental Set Up
 - 3.2.3 Foil Counting Techniques
 - 3.2.3.1 Counting Equipment
 - 3.2.3.2 U-235 Foil Counting
 - 3.2.3.3 U-238 Foil Counting
 - 3.2.3.4 Au-197 Foil Counting
 - 3.2.4 Corrected Activities
 - 3.3 Summary
- Chapter 4. Analysis of the ITS Experimental Results
 - 4.1 Comparison of the Results with State-of-the-Art Calculations
 - 4.1.1 Effect of number of energy groups
 - 4.1.2 Effect of quadrature order
 - 4.1.3 Effects of mesh size

4.2 Comparison of the Results with Previous Experiments

4.2.1 Effect of Unit Cell Structure on Self-Shielding Factor

4.2.1.1 SPHINX code

4.2.1.2 Case studies

4.3 Summary

Chapter 5. Derivation of Dancoff Factor for Cells at Interfaces

5.1 Previous Work

5.2 Dancoff Factor Correction for the Case When $G_j \neq 0$

5.3 Dancoff Factor at Interfaces

5.3.1 General formula

5.3.1 Dancoff factor for ITS

5.3.1 Cross section correction for ITS

5.3.2 Comparison of the new state-of-the-art calculations using corrected cross sections at the interface with ITS experimental results

5.4 Summary

Chapter 6. Summary, Conclusions and Recommendations

3. Advanced Blanket Investigations

Work is well underway on investigation of highly moderated external radial blankets fueled by assemblies shuffled out from radial internal blankets. In this progress report the reference core, cross section preparation and some preliminary results will be discussed.

Reference Core

The reference core has been chosen based on a study done at Argonne National Laboratory (1). In this study ANL analyzed several homogeneous and heterogeneous cores with different internal blanket arrangements. Different heterogeneous designs showed very similar neutronic and economic characteristics. The radial blanket design of the core under study here deviates from conventional fast reactor designs due to the existence of the moderator assemblies. Fig. 1 shows the planar view of the core and the radial blanket. The core consists of 780 fuel assemblies and 505 internal blanket assemblies distributed over several rings. There are three rows of external radial blanket. The first row is essentially the same as the internal blankets. The second and third rows are a mixture of moderator and blanket assemblies.

The moderator used in the radial blanket is zirconium hydride ($\text{ZrH}_{1.6}$). The major advantage of zirconium hydride over over beryllium or graphite used in other studies is the high moderating power of zirconium hydride due to its high hydrogen content. The high moderating power of zirconium hydride enables the design of the radial blanket to be much more compact compared to similar designs using beryllium, with the flexibility of changing the level of moderation without much change in the number of assemblies. There has been considerable experience with uranium-zirconium hydride fuel in the SNAP and TRIGA reactors (2,3). Zirconium hydride in the pure form has also been used in sodium-cooled reactor experiments in Germany with successful results (4). The behavior of zirconium hydride under fast neutron irradiation has also been studied in two different experiments (5). In the first set of experiments samples of zirconium hydride were irradiated at temperatures up to 580°C to fluences up to $1.15 \times 10^{25} \text{ n/m}^2 (E > 1\text{Mev})$. In the second set of experiments samples of $\text{ZrH}_{1.5}$ and $\text{H}_{1.7}$ were irradiated in EBR-II. The irradiation was at about 400°C to a fluence of $5 \text{ to } 7 \times 10^{26} \text{ n/m}^2 (E > 0.1 \text{ Mev})$. Post irradiation examinations in both cases showed very little swelling or hydrogen migration.

Cross Section Preparation

Considerable effort has been put into cross section generation. This is due to the unusual nature of the core, and especially the blanket, with a rapidly varying neutron energy spectrum across

the core. The 50 group LIB-IV microscopic cross sections were used as the basic cross section set. This set was corrected for resonance self shielding and temperature dependence using the code SPHINX. To insure that this set is adequate for the soft spectrum of the blanket a series of criticals were calculated using the transport code ANISN. The criticals were chosen to represent a wide range of spectra. The results for the thermalized criticals (much more thermalized than expected in the moderated blanket) were quite satisfactory. The shielded 50 group cross sections were next collapsed to 10 groups to be used in the burnup calculations. The structure of the 10 group cross sections is based on the ORNL 9 group set with the addition of one extra group in the thermal region (6). The sequence of calculations is shown in Fig. 2. Figure 3 shows the one dimensional radial model used for the group collapsing in SPHINX. The core is divided into two regions, where fuel and internal blanket cross sections are collapsed in the inner and outer regions. The axial blanket extensions of the blanket assemblies are collapsed in a zone 3 spectrum. The axial blanket extensions of the fuel assemblies are collapsed in a zone 4 spectrum. The control rods and sodium are collapsed in a zone 2 spectrum. For the fission products a new set of 50 group cross sections were generated based on the results reported by the Japanese Nuclear Data Committee (JNDC) (7). There are three options for the fission products cross section in the LIB IV set, including: saturating, slowly saturating and non-saturating categories. Currently there is considerable confusion about the applicability of each set for fast reactor calculations. Brookhaven National Laboratory (8) has studied this problem for their fast reactor calculations and has chosen the non-saturating set increased by a factor of 2.7, i.e., all the LIB IV fission product cross sections are multiplied by 2.7. Also, the LIB IV fission products do not have any scattering matrix, but this should not introduce any significant error. The JNDC's study was based on the 28 most important nuclides which constitute about 80% of the total capture by fission products. This study was supplemented by the study done by Cook for other nuclides (9). This set has a complete down scattering matrix. Benchmark calculations based on integral measurements has shown that this set gives a better agreement than the ENDFB/4 fission product set. The JNDC fission product cross section set is given for 70 energy groups. This set was collapsed to the LIB IV 50 groups energy structure based on a typical fission and 1/E spectrum. Table 1 shows the ratio of the JNDC's 50 group fission product capture cross sections to the LIB IV's cross section set. The LIB IV values include the 2.7 factor mentioned earlier.

Preliminary Results and Future Plans

As has been described in previous reports, the basic fuel management strategy used in the core under study is to build up plutonium in the internal blankets, and then to move the internal blanket after a few cycles of burnup in the core to the external

Fig. 1. Planar View of the Core

Fig. 2. Sequence of Calculations

Zone No.

Zone

1	Internal Blanket (inner core)
2	Fuel (inner core)
3	Internal Blanket (outer core)
4	Fuel (outer core)
5	Radial Blanket Row 1
6	Radial Blanket Rows 2 & 3
7	Radial Shield

Fig. 3. The One Dimensional Model of the Core Used in Cross Section Collapsing

Table 1.

Fission Product Capture Cross Section Ratio of JNDC to LIB IV(50 groups)

<u>Group</u>	<u>$\sigma_c^{\text{JNDC}} / \sigma_c^{\text{LIB IV}}$</u>	<u>Group</u>	<u>$\sigma_c^{\text{JNDC}} / \sigma_c^{\text{LIB IV}}$</u>
1	0.07937	26	1.15834
2	0.18915	27	1.18386
3	0.53271	28	1.23698
4	0.96746	29	1.20836
5	1.17042	30	1.22464
6	1.20366	31	1.26440
7	1.24069	32	1.29982
8	1.27833	33	1.59619
9	1.29605	34	1.52277
10	1.29803	35	1.07200
11	1.23524	36	0.72979
12	1.16735	37	1.40743
13	1.14966	38	1.40306
14	1.14659	39	2.78448
15	1.14898	40	0.96248
16	1.15344	41	3.03949
17	1.15711	42	1.58189
18	1.15979	43	9.35697
19	1.16517	44	10.68521
20	1.18013	45	1.90879
21	1.18096	46	72.22638
22	1.17810	47	18.38698
23	1.17150	48	31.07376
24	1.16405	49	61.69649
25	1.16184	50	7.24559

moderated blanket. Jenks in his study indicated that the highest rate of plutonium buildup could be achieved not in the hardest spectrum possible, but in a somewhat softer spectrum (10). Since for the present study it is important to build in as much plutonium in the internal blankets as quickly as possible, this point was studied further. The first study was based on an infinite homogeneous medium having typical internal blanket composition. Several cases were considered, one typical of conventional internal blankets and three more cases having 10%, 20% and 30% by volume of Be added. The resulting Pu²³⁹ build up for several burnup cycles is shown in Table 2. Each 300 days of burnup corresponds to a year at 82% capacity. It can be seen that the Pu²³⁹ build up actually goes through a peak, but it is not too pronounced. The basic problem with the infinite homogeneous study was the fact that the system was quite subcritical and the spectrum was already softer than what is normally expected in an internal blanket. To correct this a more realistic geometry of an internal blanket surrounded by two rings of fuel is now being studied (10).

Future plans include detailed analysis of fuel management options for the core under study using the two dimensional burnup code 2DB. This analysis also includes looking at metal fuel and the possible use of thorium in the internal blankets. Several design options for the moderator assemblies will also be studied.

Table 2
 Pu^{239} Build Up Change with Spectrum

<u>Days of Burnup</u>	<u>$\text{Pu}^{239}/\text{Pu} + \text{U}, \%$</u>			
	<u>Regular IB</u>	<u>10% Be</u>	<u>20% Be</u>	<u>30% Be</u>
300.0	3.016	3.197	3.394	3.406
600.0	4.057	4.301	4.489	4.439
900.0	4.829	5.105	5.248	5.128

References

1. Barthold, C.P. and C.P. Tzanos, "Performance Potential of Reference Fuel in 1200 MWe LMFBRs" FRA-TM-104, November 1977.
2. Little, A. F., et al., "Zirconium Hydride Fuel Element Performance Characteristics," USAEC Report AI-AEC-13084, Atomics International, June 19, 1973.
3. Simnad, M.T., et al., "Fuel Elements for the TRIGA Mark III Reactor," Trans. Am. Nucl. Soc. 7, 110 (1964).
4. Harde, R., and K.W. Stoeher, "A Sodium-Cooled Power Reactor Experiment Employing Zirconium-Hydride Moderator," in the Third Geneva Conference Proceedings, United Nations, Geneva, 1965.
5. Pacts, P., "Neutron Irradiation Effects on Zirconium Hydride," J. Nucl. Mater. 43, 13 (1972).
6. Tomlinson, E.T., "Neutronic Analysis of LMFBRs During Severe Core Disruptive Accidents," ORNL-CSD-35, January, 1979.
7. Kikuchi, Y., et al., "Fission Product Fast Reactor Constants System of JNDC," JAERI, November 1976.
8. Fischer, C. J., et al., "The Fast-Mixed Spectrum Reactor Interim Report," Draft, December 1978.
9. Cook, J. L., "Fission Product Cross Sections," AAEC/TM-549 (1970).
10. Jenks, T. S., "Feasibility of Breed/Burn Fuel Cycles in Pebble Bed HTGR Reactors," M.I.T., M.S. Thesis, September 1978.
11. Rogus, R., 22.901 Special Problem, M.I.T. Nuclear Engineering Department, Spring, 1979.

4. Administrative Matters

The monthly financial statement for December is attached: it also includes FY totals to date.

As of December 31, 1978 the project staff was as follows:

Staff

M. J. Driscoll, principal investigator

R. Morton, part-time Computer Operations Assistant

Students

B. Atefi, ScD thesis student, Research Assistant

M. Saidi, ScD thesis student

G. Nakayama, part-time Research Assistant

W. J. Glantschnig, part-time Research Assistant

FAST REACTOR BLANKETS

RESTRICTIONS				CURRENT MONTH	FISCAL YEAR TO DATE	CUMULATIVE
EXPENDITURES				12/31/78		
SALARIES AND WAGES						
FAC SAL-TEN			13,359.00	604.45	2,568.90	8,191.12
SUMMER FACULTY-ON			15,581.00			
RESEARCH STAFF-ON			4,811.00	160.56	896.47	2,644.44
HOURLY PERSONNEL-ON			2,000.00		130.52	572.86
SECRETARIAL & CLERICAL-ON			2,365.00	120.00	609.83	2,209.58
EXEMPT-TECH-ON				357.50	1,548.20	12,771.29
TOTAL SUBJECT TO E. B.			38,116.00	527.51	5,753.92	26,389.29
GRADUATE STUDENT STAFF-ON				85.00	361.25	361.25
RESEARCH ASSISTANT-ON			28,770.00	1,440.00	5,280.00	12,440.00
MIT STUDENTS-ON					1,533.75	2,342.58
UNDERGRAD SALARIES-UROP						495.26
TOTAL SALARIES AND WAGES			66,886.00	2,052.51	12,928.92	42,028.38
EMPLOYEE BENEFITS ON OFF						
BILLING RATES	26.00%	30.00%	9,910.00	137.15	1,496.02	6,861.21
TOTAL OPERATING EXPENSES			13,012.00	313.68	1,631.68	9,306.01
COMPUTATION EXPENSES						
E.D.P. EXPENSE				3.87	436.34	1,361.71
I.P.C. CHARGES			11,000.00		6,565.95	12,029.98
TOTAL COMPUTATION EXPENSES			11,000.00	3.87	7,002.29	13,391.69
PREPAID EXPENSES						
TRAVEL ADV & TICKETS					120.00	120.00
INDIRECT EXPENSES ON OFF						
BILLING RATES	67.00%	15.00%	41,192.00	984.67	7,895.90	27,952.89
ADJ TO ACTUAL	66.00%	16.00%		14.69	117.85	117.85
TOTAL INDIRECT EXPENSES			41,192.00	969.98	7,778.05	27,835.04
TOTAL EXPENDITURES			148,000.00	3,477.19	30,956.96	99,542.33
UNEXPENDED BALANCE						50,053.37
PURCHASE ORDER COMMITMENTS						505.00
UNCOMMITTED BALANCE						49,548.37

PhD Thesis Prospectus

An Assessment of the Use of Internal Blankets in
Gas Cooled Fast Breeder Reactors

by

Dale Lancaster

February 1979

Massachusetts Institute of Technology
Department of Nuclear Engineering

Advisor: Professor M. J. Driscoll

mjd

Reader: Professor D. D. Lanning

PhD THESIS PROSPECTUS

Title: An Assessment of the Use of Internal Blankets
in Gas Cooled Fast Breeder Reactors

Thesis Advisor: M. J. Driscoll

Thesis Reader: D. D. Lanning

Submitted by: Dale Lancaster

Introduction and Background

During the past few years there has been a growing trend to include internal blankets in LMFBR core designs. This change has resulted in lower sodium void worths and higher breeding ratios. The effect on fuel cycle economics is less certain: along with the higher breeding ratio higher fuel inventories are also required. Doubling time improvements associated with the use of internal blankets are ascribed by some to the use of off-optimum pin sizes in the fuel. ^(1,2) Hence, at present the major point in favor of internal blankets in the LMFBR appears to be the lowering of the sodium void worth. Since there is no major problem with coolant void worth in a GCFR, there has not been as much interest in putting internal blankets in a gas cooled core. However, the debate over the breeding-related advantages has never been fully resolved, and still other advantages have been ascribed to internal blankets in LMFBR's. Thus assessment of the consequences and attributes of using internal blankets in GCFRs appeared to be a worthwhile

objective, a goal which is the major focal point of the research proposed here.

Work on internal blankets has been conducted for some time at MIT, ^(3,4,5) primarily on axial parfait designs (use of blanket zones in fissile-fueled fuel pins). These designs have exhibited some attractive advantages but do not show as much promise as internal blanket assemblies in what is called a "radial heterogeneous" design (use of radial blanket assemblies inside the fissile-fueled core zone). The radial heterogeneous design has a higher breeding ratio because of the increased heavy metal loading enveloped by the core. This increase is possible since blanket assemblies, due to their lower power, have higher fuel fractions than fissile-fueled assemblies. Thus the present study will deal mainly with radially heterogeneous core designs.

Discussion of Potential Benefits

From the recent LMFBR studies and the early axial parfait studies a number of benefits are expected in the GCFR.

1) The internal blankets will increase the breeding ratio (at the same time the fissile inventory will increase). The increase in breeding ratio will hopefully outweigh the increased fissile inventory, in which case the doubling time will decrease.

2) It should be possible to flatten the power distribution with internal blankets rather than through use of multiple enrichment zones. This will allow using only one feed enrichment.

3) The higher breeding ratio will result in less of a reactivity swing with burnup. This will lessen the number (and/or individual worth) of control rods needed. Further, this should decrease the magnitude of some transients since the initial excess reactivity is less.

4) Since the enrichment is higher in the core zones the flux is less. Thus fluence-induced swelling and bowing will be reduced.

5) The heterogeneous nature of the core design will prevent large coherent effects. For example, any material dispersal that might occur during an accident will occur at different times in the fuel and blanket, which will help mitigate large transients.

All of these advantages must be quantified and better understood. Thus there is a strong need for acquisition of the information sought in this thesis.

Scope of the Thesis

The thesis will investigate various arrangements of internal blankets in a GCFR and attempt to quantify the phenomena already discussed. A reference heterogeneous design will be selected and a detailed comparison of homogeneous to heterogeneous core properties will be performed. The comparison will include expected benefits and problems in many disciplines including reactor physics, thermal-hydraulics, material science, safety analysis, and mechanical design.

Most of the analysis will be based on use of conventional fuels (PuO_2/UO_2) and the plutonium/uranium fuel cycle. However work will be included on the impact of internal blankets in a GCFR on the cross-progeny fuel cycle, in which thorium internal blankets are used to generate fuels for thermal reactors.

The thesis work is being funded by a contract with General Atomic.

References

- (1) W.P. Barthold, J. Beitel, E. Khan, and C. Tzanos, "Potential and Limitations of the Heterogeneous Reactor Concept," Trans. Am. Nucl. Soc. 26, 552-553 (1977).
- (2) Y. Orechwa, M.J. King, and R.B. Turski, "Potential and Limitations of Heterogeneous Reactor Concepts v. Pin Diameter Optimization in 1200 MW_e Heterogeneous vs. Homogeneous LMFBRs," FRA-TM-112, Apr. 20, 1978.
- (3) M.J. Driscoll et al., "Safety and Breeding-Related Aspects of Fast Reactor Cores Having Internal Blankets," International Meeting on Fast Reactor Safety and Related Physics, Chicago, Oct. 1976.
- (4) D.C. Aldrich, "Parfait Blanket Systems Employing Mixed Progeny Fuels," SM Thesis, MIT Nuclear Engineering Department, June, 1976.
- (5) G.A. Ducat, M.J. Driscoll, and N.E. Todreas, "Evaluation of the Parfait Blanket Concept for Fast Breeder Reactors," COO-2250-5, MITNE-157, January 1974.

SM Thesis Prospectus

Evaluation of the Fast-Mixed Spectrum Reactor

by

Wee Tee Loh

February 1979

Massachusetts Institute of Technology
Department of Nuclear Engineering

Thesis Supervisors: Professor M.J. Driscoll
Professor D.D. Lanning

mjd
DDL

SM THESIS PROSPECTUS

Title: Evaluation of the Fast-Mixed Spectrum Reactor

Thesis Supervisors: M.J. Driscoll, D.D. Lanning

Submitted by: Wee Tee Loh

Introduction:

A number of unconventional design concepts related to the fast reactor core have been investigated in recent years. The basic objectives of these designs include enhanced safety features, such as lower sodium void coefficients, and better neutronic performance, such as higher breeding ratios. The objective of the present work is to evaluate a new concept in fast reactors for the production of electric power--the Fast-Mixed Spectrum Reactor (FMSR), which has enhancement of proliferation resistance as its major focus.

Background:

Several core designs utilizing uranium and thorium blankets have been studied at MIT, as part of the Nuclear Engineering Department's Fast Reactor blanket project.

Studies on internal blankets, in particular the 'parfait blanket,' have shown that the associated core designs have improved safety features such as decreased sodium void coefficient (25-30%), decreased sodium temperature coefficient (40%) and better

neutronic performance, such as increased breeding ratio (2%).

[1-3]. The disadvantages of these cores include increased core fissile inventory (4%), reduced Doppler power coefficient (8%) and reduced delayed neutron fraction (1%).

The latest effort on improving both the safety and neutronic performance of the core has focussed on internal radial blankets [5], and some advanced blanket design concepts such as moderated and fissile seeded blankets [6].

The Fast-Mixed Spectrum Reactor concept as proposed by G. J. Fischer et al at BNL [10] is in some ways an extension of the heterogeneous fast breeder reactor, and is also a variation of the coupled fast-thermal reactor studied by R. Avery [7-9]. The basic concept is as follows:

The core consists of a central hard spectrum region surrounded by a moderator zone consisting of beryllium. The reactor could be started up on medium enriched uranium (~7% enrichment). Fresh fuel (depleted or natural uranium) is first loaded into the moderated region. The fuel remains in this region until the bred plutonium enrichment reaches approximately 2.7%, at which time the fuel is shuffled to the fast region. In this region the plutonium content increases until it reaches 7% enrichment at the time of discharge from the region. The FMSR is designed to be self-sustaining on an equilibrium feed of natural or depleted uranium alone.

The FMSR has obvious nonproliferation advantages and it can achieve good utilization of uranium resources. The fuel cycle costs will be less than those of a more conventional fast breeder.

Present Work:

The objective of the present work is to carry out an independent evaluation of the neutronic characteristics of a gas-cooled FMSR core design, under subcontract from BNL.

Static beginning of equilibrium cycle reactivity calculations and fuel burnup studies will be carried out using available state-of-the-art computer codes and cross-section sets.

Cross-sections for the core will be generated using a 50 group fast cross section library (LIB-IV), corrected for self-shielding using the SPHINX code. Burnup calculations will be performed using these cross sections in the computer code 2DB. Finally, gamma heating distributions will be examined using a coupled neutron-gamma cross section set, paralleling the prior work at MIT by Kalra [11]

Time Schedule

- Define reference case with BNL (2/1/79)
- Generation of cross-section sets
- Burnup Analysis:
 - Calculations of K_{eff} , breeding ratio, fluence, composition, flux and power distribution of equilibrium core at the beginning of cycle
- Comparison of results with BNL (4/1/79)
- Investigation of discrepancies
- Calculation of K_{eff} , etc. of equilibrium core at the end of cycle
- Comparison of results with BNL
- Gamma heating distribution (6/1/79)
- Submit first draft of report (7/15/79)
- Submit final report/S.M. Thesis (8/15/79)

References

- (1) G.A. Ducat, M.J. Driscoll and N.E. Todreas, "Evaluation of the Parfait Blanket Concept for Fast Breeder Reactors," COO-2250-5 (1976).
- (2) R.A. Pinnock, "Parfait Blanket Configurations for Fast Breeder Reactors," S.M. Thesis, MIT Nuclear Engineering Dept. (1975).
- (3) D.C. Aldrich, "Parfait Blanket Systems Employing Mixed Progeny Fuels," S.M. Thesis, MIT Nuclear Engineering Dept. (1976).
- (4) M.J. Driscoll, G.A. Ducat, R.A. Pinnock, D.C. Aldrich, "Safety and Breeding-Related Aspects of Fast Reactor Cores Having Internal Blankets." MIT Nuclear Engineering Dept. (1976).
- (5) W.P. Barthold and C.P. Tzanos, "Performance Potential of a Reference Fuel in 1200 MWe LMFBR's" (1977).
- (6) J.I. Shin and M.J. Driscoll, "Evaluation of Advanced Fast Reactor Blanket Design," COO-2250-25 (1977).
- (7) R. Avery, "Coupled Fast-Thermal Power Breeder," Nucl. Sci. Eng. 3, 129 (1958).
- (8) R. Avery, "Theory of Coupled Reactors," Int. Conf. on Peaceful Uses of Atomic Energy, Geneva, p. 182 (1958).
- (9) R. Avery, et al., "Coupled Fast-Thermal Power Breeder Critical Experiment," Int. Conf. on Peaceful Uses of Atomic Energy, Geneva, p. 151 (1958).

- (10) G.J. Fischer and R.J. Cerbone, "The Fast-Mixed Spectrum Reactor," Dept. of Nucl. Energy, BNL. December, 1978.
- (11) M.S. Kalra and M.J. Driscoll, "Gamma Heating in LMFBR Media," COO-2250-18, MITNE-179, February 1976.