MASTER

COO-2250-34

MIT LMFBR BLANKET RESEARCH PROJECT

Quarterly Progress Report
July 1, 1978 - September 30, 1978

Principal Investigator
Michael J. Driscoll

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.

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

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

October 20, 1978

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

There is no objection from the patent
point of view to the publication or
dissemination of the document(s)
listed in this letter.

BROOKHAVEN PATENT GROUP

12/5/78 By *[Signature]*

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-2250-34

Distribution

MIT LMFBR Blanket Research Project
Quarterly Progress Report

Department of Energy Research and Development
Contract YE-76-S-02-2250
UC-79P LMFBR-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

1. General

Blanket mockup No. 6 has been placed in standby status. Excess fuel is being inventoried prior to its return to DOE custody. The special sodium-filled assembly has been dismantled. No experiments are planned during the final quarter of CY 1978.

The draft paper on thorium assembly experiments appended to the preceding quarterly report (1) has been accepted for presentation at the November ANS meeting in Washington, D.C.

2. An Improved Dancoff Factor Prescription for FBR Applications

The use of the so-called Dancoff correction to allow for the effects of pin-to-pin shadowing on the effective cross sections for resonance absorbers has become a well-established procedure in reactor physics calculations. While developed primarily for thermal reactor applications, its use has been carried over in an essentially unmodified form for FBR applications in cross section processing codes such as SPHINX.⁽²⁾ In thermal reactors essentially all of the neutron slowing down source is concentrated in the moderator region of the unit cell; in fast reactors on the other hand, an appreciable fraction of the slowing down can take place in the fuel. This reduces the self-shielding of resonant fuel isotopes, a phenomenon which can be allowed for by modifying the Dancoff factor.

The effective group absorption cross section for a resonance absorber in the fuel of a 2-region unit cell can be written in the form:

-
- (1) MIT LMFBR Blanket Research Project, Quarterly Progress Report, April 1, 1978-June 30, 1978, COO-2250-33, July 28, 1978.
- (2) W.J. Davis, M.B. Yarbrough and A.B. Bortz "SPHINX, a One Dimensional Diffusion and Transport Nuclear Cross Section Processing Code," WARD-XS-3045-17, Aug., 1977.

$$\sigma_a^{\text{het}} = \frac{\int_{\Delta E} \frac{\lambda \Sigma_{\text{pf}} + \kappa \Sigma_{\text{sfn}} + \mu \Sigma_{\text{m}}}{\Sigma_{\text{af}}(E) + \lambda \Sigma_{\text{rf}}(E) + \kappa \Sigma_{\text{sfn}} + \mu \Sigma_{\text{m}} R(E)} \sigma_{\text{af}}(E) \frac{dE}{E}}{\int_{\Delta E} \frac{\lambda \Sigma_{\text{pf}} + \kappa \Sigma_{\text{sfn}} + \mu \Sigma_{\text{m}}}{\Sigma_{\text{af}}(E) + \lambda \Sigma_{\text{rf}}(E) + \kappa \Sigma_{\text{sfn}} + \mu \Sigma_{\text{m}} R(E)} \frac{V_{\text{f}}/V_{\text{c}} + (V_{\text{m}}/V_{\text{c}})R(E)}{\frac{dE}{E}} dE} \quad (1)$$

where

λ, κ, μ are the intermediate resonance parameters (1, 1, 1 for the narrow resonance approximation, and 0, 1, 1 for the wide resonance approximation--calculated for each resonance using, for example, the prescriptions in Ref. (2))

Σ = volume-homogenized macroscopic cross section

pf - potential scattering by resonance absorber
 rf - resonance scattering by resonance absorber
 af - absorption by resonance absorber
 sfn - scattering by non resonance material in fuel
 m - scattering by moderator (clad + coolant)

and

$R(E)$ = ratio of mean flux in moderator region to that in fuel region.

The key to practical exploitation of this approach is, of course, development of a simple prescription for $R(E)$. We have generalized previous results reported by Kadiroglu for this purpose⁽³⁾, through which it is possible to calculate $R(E)$

(2) H. Haggblom, "Computation of Resonance-Screened Cross Sections by the Dorix-Speng System," AE-334 (1968).

(3) O.K. Kadiroglu and M.J. Driscoll, "Uranium Self-Shielding in Fast Reactor Blankets," COO-2250-17, MITNE-179, March 1976.

(4) A.A. Salehi, M.J. Driscoll and O.L. Deutsch, "Resonance Region Neutronics of Unit Cells in Fast and Thermal Reactors" COO-2250-26, MITNE-200, May 1977.

as an explicit function of the parameters defined above plus the fraction of the slowing-down source originating in each region, and the mean Dirac chord for each region ($\ell = 4V/S$). The functional form of the relation for $R(E)$ was developed using collision probability theory and the numerical accuracy has been verified using S_N and Monte Carlo calculations.⁽⁴⁾

Linearization of the expression for $R(E)$, by using group averaged values for the optical thicknesses involved ($\tau = \Sigma \cdot \ell$), permits one to cast Eq. (1) into the form of an equivalence relationship, such that the corresponding Bondarenko f-factor for the heterogeneous cell can be expressed as the f-factor for a homogeneous cell at a modified value of the background scattering cross section, σ_0 . In this linearization we take advantage of the fact that the dominant contribution to the integrals of Eq. (1) is in the wings of the resonances, and thus a weak absorption limit can be employed (3). It should also be noted that linearization of $R(E)$ appears to be a mathematically necessary and sufficient condition to permit definition of equivalence relationships.

Furthermore, examination of the expression derived in this manner for σ_0 permits identification of one of the terms as the Dancoff factor, $(1-C)$. If there is no slowing down source in the moderator the expression for $(1-C)$ takes on the form of Bell's approximation (5) with a near-optimum value of the Levine correction factor (6). The derivation up to this point has been documented in Ref. (4).

We can, however, generalize upon the preceding results, since $R(E)$ and expressions derived from it are a function of the fraction of the slowing down source in the fuel region, Q_f . By comparing the results of parallel derivations with $Q_f = 0$ and $Q_f \neq 0$, a modified Dancoff correction can be identified:

$$(1 - C') = \frac{1}{1 + \frac{1}{3} Q_f (1-C)} (1-C) \quad (2)$$

(The factor $1/3$ in the denominator on the RHS of Eq. (2) represents the weak interaction asymptote: the strong interaction asymptote is 1.0)

- (5) G.I. Bell, "A Simple Treatment for Effective Resonance Integrals in Dense Lattices," Nucl. Sci. Eng., 5, 138(1959).
 (6) M.M. Levine, "Resonance Integral Calculations for U²³⁸ Lattices," Nucl. Sci. Eng., 16, 271(1963).

where

Q_f = fraction of slowing down source generated in the fuel

$$\left(= \frac{\xi_f \tau_f}{\xi_f \tau_f + \xi_m \tau_m} \right)$$

ξ = logarithmic mean energy decrement for elastic moderation (which dominates in the region of interest) $\left(\approx \frac{2}{A} \right)$

Note that Eq. (2) reduces to $(1-C') = (1-C)$ when $Q_f = 0$ and to $(1-C') = 0$ (no shadowing) when $(1-C) = 0$, as is to be expected. For a typical LMFBR unit cell Q_f can assume values on the order of 0.5, hence if $(1-C) = 0.5$, $(1-C') = 0.92$, which is only a modest correction.

Thus moderation in the fuel can have an effect on the Dancoff correction for fast reactors. Fortunately the consequences of neglecting this phenomenon do not appear to be severe in most applications, since only the low energy tail of the neutron spectrum is affected. Nevertheless the approximate correction outlined here is so easily applied that it would appear advisable to employ it.

Work continues to determine whether there are situations in which this correction may in fact lead to non-negligible changes in computations of quantities of interest. Our primary interest here, of course, is in interface-related effects.

3. Breed/Burn Blanket Management

Work continues on an evaluation of the practicality of moving internal blanket elements into a moderated external blanket after the assemblies have built up several per cent fissile enrichment in the in-core position. The focus is on the use of thorium because of its superiority in an epithermal blanket.

In work done under partial support from the project⁽¹⁾ it was found that the maximum asymptotic enrichment in an internal blanket is attained in an ambient spectrum which is somewhat softer than in a typical LMFBR core, but harder than a highly undermoderated thermal reactor. Figure 3.1 summarizes the results of this analysis. Thus it may be preferable to include BeO in internal blanket fuel if rapid acquisition of the highest possible enrichment is the objective.

FIGURE 3.1: ASYMPTOTIC ENRICHMENTS FOR U233/Th SYSTEMS

We are presently carrying out more detailed calculations to confirm these results, to fill in the speculative region shown in the figure, and to determine the k_{∞} of the as-bred fuel assemblies when additional moderator is added, simulating the external blanket environment.

4. Administrative Matters

The monthly financial statement for September is attached; it also includes FY totals to date.

As of September 30, 1978 the project staff was as follows:

Staff

M.J. Driscoll, principal investigator

A.T. Supple, part-time Engineering Assistant
(terminating as of 9/30/78)

R. Morton, part-time Computer Operations Assistant

Students

B. Atefi, ScD thesis Student, Research Assistant

M. Saidi, ScD thesis student

D. Lancaster, Research Assistant (prior to 8/78)

G. Nakayama, part-time Research Assistant

W.J. Glantschnig, part-time Research Assistant

(1) T.S. Jenks, Reasibility of Breed/Burn Fuel Cycles in Pebble Bed HTGR Reactors, SM Thesis, MIT Nucl. Eng. Dept., Sept., 1978.

FAST REACTOR BLANKETS

RESTRICTIONS		CURRENT MONTH	FISCAL YEAR TO DATE	CUMULATIVE
EXPENDITURES		SEPT '78		
SALARIES AND WAGES				
FAC SAL-TEN	7,903.00	755.56	755.56	6,377.79
SUMMER FACULTY-ON	15,581.00			
RESEARCH STAFF-ON	2,351.00	200.70	602.10	2,350.07
HOURLY PERSONNEL-ON	2,000.00		14.28	456.62
SECRETARIAL & CLERICAL-ON	2,365.00	74.25	201.03	1,800.83
EXEMPT-TECH-ON		520.49	2,635.55	8,587.54
TOTAL SUBJECT TO E. B.	30,200.00	1,551.00	1,062.53	19,572.94
GRADUATE STUDENT STAFF-ON			106.25	106.25
RESEARCH ASSISTANT-ON	11,028.00	960.00	960.00	8,120.00
MIT STUDENTS-ON		334.00	1,523.75	2,342.58
UNDERGRAD SALARIES-UROP				495.26
TOTAL SALARIES AND WAGES	41,228.00	2,845.00	1,527.47	30,636.93
EMPLOYEE BENEFITS ON OFF				
BILLING RATES 26.00% 30.00%	7,852.00	403.26	276.25	5,083.94
OPERATING EXPENSES				
TOTAL OPERATING EXPENSES	10,166.00	33.17	532.83	8,207.16
COMPUTATION EXPENSES				
E.D.P. EXPENSE		64.16	297.33	1,222.70
I.P.C. CHARGES	6,000.00	683.34	3,724.11	9,138.14
TOTAL COMPUTATION EXPENSES	6,000.00	747.50	4,021.44	10,410.84
OTHER CHARGES				
OTHER CHARGES	6,000.00			
INDIRECT EXPENSES ON OFF				
TOTAL INDIRECT EXPENSES	28,754.00	1,827.05	515.60	20,572.59
TOTAL EXPENDITURES	100,000.00	5,855.98	6,331.09	74,916.46