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MIT LMFBR BLANKET RESEARCH PROJECT

**Quarterly Progress Report
January 1, 1979 - March 31, 1979**

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1. General

This report summarizes work completed, in progress, or planned since our last quarterly report: MIT LMFBF Blanket Research Project, Quarterly Progress Report, October 1, 1978 - December 31, 1978, COO-2250-35.

Twelve fuel shipping containers have been received on site and loaded with surplus fuel rods. Paperwork is now in progress to initiate return of this fuel to DOE. Presuming continued availability of the shipping containers, and funding capability, it is currently estimated that four shipments should reduce the on site inventory to a current-and-projected needs level.

Approximately two-thirds of the initial draft of a topical report on our interface measurements and calculations has been edited. This report will be completed and issued during the coming quarter, and this area will no longer be reported on in the quarterlies. The report will be by M. S. Saidi and M. J. Driscoll and titled, "Interfacial Effects in Fast Reactors," COO-2250-37, May 1979.

2. Advanced Blanket Investigations

Work continues on the use of substantial moderator additions to the radial blanket, coupled with shuffling of internal blanket elements into the external blankets (a breed/burn fuel cycle). This would offer a number of potential benefits including provision of a greater power bonus from the blanket, and flattening of radial blanket power. In addition, if use of thorium fuel is contemplated, this may further enhance the attractive features of this concept.

2.1 Introduction

The basic concept (as described in previous progress reports) is to breed plutonium in depleted uranium fueled internal blankets (or U-233 in thorium fueled internal blankets) and then to move the internal blanket assemblies into the radial blanket and there to burn the fissile isotopes to the maximum extent practicable. This strategy should lower the steady state core enrichment required: the critical fissile Pu enrichment of an infinitely large (no leakage) fast reactor core is around 8.5%. The critical enrichment of a large (~ 1000 MWe) but finite homogeneous fast reactor core is around 15% (and for a heterogeneous core around 19%). The difference in the critical enrichment of an infinite (no leakage) system with a realistic core is basically due to the large leakage of core neutrons to the radial and axial blankets. In a conventional fast reactor the 25 to 30% of the core neutrons that leak to the blankets are used to breed plutonium. If the leakage to the radial blanket can be substantially reduced, then the steady-state core enrichment can be reduced to values closer to those for an infinite homogeneous system. One way of doing this is to replace the radial blanket with a system that does not act like a neutron sink: in particular, a critical or near-critical system. If enough plutonium or U-233 can be bred in the internal blankets, in a reasonable time, the internal blanket can be moved to the radial blanket to create a critical system. This shuffling scheme has the added advantage of deferring or eliminating the reprocessing requirement for the internal or radial blankets.

The rate of buildup of plutonium in the internal blankets varies radially and axially; on the average, close to 2% plutonium can be built in annually for each of the first two years, but the rate of build up falls off thereafter as the saturation limit of plutonium is approached. Based on this observation, a critical plutonium radial blanket (which requires approximately 8.5% fissile plutonium) cannot be achieved in a reasonable time span. We have evaluated what can be achieved, however, to determine whether the benefits are still worthwhile.

Fuel Assembly

Internal Blanket Assembly

Radial Blanket Assembly

Shield

Fig1. Planar View of the Core

Unlike the U-Pu system, however, an epithermal Th-U₂₃₃ system (moderated by zirconium hydride, for example) requires only 3.5% to 4% U₂₃₃ to go critical. Thus it might be possible to breed enough fuel in the internal blanket to feed a critical external blanket. This system is currently under study.

2.2 Fissile Build-up in Internal Blankets

Since the rate of plutonium or U-233 buildup in the internal blanket is an important parameter in the present work, a separate study was performed on ways to enhance the rate of fissile buildup (1).

Originally there were indications that softening of the spectrum in internal blankets would increase the rate of fissile build up. This thought was reinforced by the fact that the ratio, $\frac{\sigma_c^{28}}{\sigma_a^{49}}$,

which is directly related to fissile buildup peaks around 10 KeV. The results of the study showed that spectrum softening does not help the rate of fissile buildup, but actually degrades the rate of buildup. The basic explanation for this result in the light of the above argument is that selective softening of the spectrum to create a peak around 10 KeV is not possible: softening occurs over a broader range, and the net effect is detrimental. It was concluded that the highest rate of fissile buildup can be achieved in the hardest blanket spectrum. Based on this conclusion uranium or thorium metal are the most desirable materials for the internal blankets as far as fissile buildup is concerned. These materials will be considered further in the study of internal blanket designs.

2.3 Reference Cores

The planar view of the core used in concept evaluation is shown in Fig. 1. The core consists of 780 fuel assemblies and 415 internal blanket assemblies. The number of rows of radial blanket assemblies depends on the amount of moderator rods desired. For example, there are 414 assemblies in a three-row radial blanket. This number is equal to the number of internal blanket elements. Thus with no extra-assembly moderation all internal blankets can be moved to radial blankets in a three row configuration. Four rows of radial blanket equals 564 assemblies, and this allows for 27% extra-assembly moderator by volume. Higher moderator content is possible if the number of radial blanket positions is increased. Although both ex-assembly and in-assembly moderation is being considered, the latter concept is currently favored. Beyond the radial blanket there are three rows of radial shield.

Fig 2. Core Configuration for RZ Burnup Calculations

Fig 3. Assembly Design

Cross section generation methods have been described in detail in the last progress report. Basically a 10 group cross section set was generated from the 50 group LIB-IV cross section set (2), based on the actual geometry through the 1-DX portion of SPHINX (3). Figure 2 shows the R-Z layout of the upper half of the core used in burnup calculations by the two-dimensional burnup code 2DB (4). There are 64 radial mesh and 24 axial mesh points. Axially the core, internal blanket and radial blanket assemblies are cut into three different zones; the axial blanket is cut into two zones axially. In this way the R-Z layout is divided into 78 burnup zones.

The fuel assemblies consist of 217 fuel pins having an 0.23 inch outside diameter. The internal blanket assemblies consist of 127 pins of 0.346 inch outside diameter. For the moderated external blankets, depending on the level of moderation desired, space will be left for zirconium hydride pins. Fig. 3 shows a preliminary design of a blanket with 28 moderator pins. It is interesting to note that this type of design has been proposed for heterogeneous cores which have internal blanket rods as an integral part of their fuel assemblies rather than as separate assemblies (5).

2.4 Power Peaking

One of the points of concern in using moderator rods in blanket assemblies is the power peaking problem. Since the number of moderator pins per assembly is a function of the level of moderation desired, an assembly with very high moderation (worst case) was studied. In this assembly there are 49 moderator rods, corresponding to 38 volume percent moderator content. The peaking was analyzed for an assembly in the first row of the radial blanket at the central plane of the core, where the highest power density exists. The peaking occurs at the position where the blanket rod is surrounded by the moderator pins. From this analysis the peak-to-average midplane pin power ratio is calculated to be 1.224, which corresponds to a peak linear heat generation rate of 14.85 KW/ft. The design limit for the peak linear heat generation rate (3σ, 15% overpower) is 20.0 KW/ft. Thus it can be concluded that in the proposed moderated blankets the peak rod is well below the specified design limit.

Another point of concern in using zirconium-hydride is the radiation damage to the rods. Based on our calculations, and comparison with the experimentally available data it is concluded that the fluence experienced by the zirconium hydride rods over several cycles is below the level experimentally proved to cause no significant damage.

2.5 Results and Future Plans

The study of the core with depleted uranium internal blanket is nearly complete. As was mentioned earlier, due to the high critical enrichment requirements of the U-Pu system (8.5%) and the low plutonium buildup rate in the internal blanket (~2% per year) not enough plutonium can be built in the internal blankets to create a critical radial blanket after shuffling. Also, in the U-Pu system moderation does not help, since the epithermal U-Pu system requires a higher critical enrichment (due to the lower η of fissile plutonium) than the fast U-Pu system.

However, transferring internal blankets to the radial blanket increases the fraction of the power generated by the radial blanket assemblies, which will result in a lower number of fuel assemblies and a smaller core. To see this, refer to Table 1, which shows the fraction of power generated by various parts of the core at the BOEC. The total power in MWth adds up to 1500 MWth generated by the upper half of the core (i.e., the total power of the core is 3000 MWth, corresponding to 1200 MWe based on a 0.4 thermal efficiency). Table 2 shows the same data for the case where all the internal blanket assemblies have been transferred to the three-row radial blanket after two years of burnup. The same results for a four-row moderated blanket is shown in Table 3.

Table 1
Power Generated by Various Parts of the Reactor
at the BOEC

	<u>Power (MWth)</u>	<u>Percent</u>
Core	1366.43	91.09
Internal Blankets	99.20	6.61
Axial Blankets	24.41	1.62
Radial Blankets	9.95	0.68

NOTE: Radial blanket is fresh (depleted uranium); subsequent comparisons will also be made with radial blankets having equilibrium plutonium content.

Table 2
Power Generated by Various Parts of the Reactor with
Internal Blankets Transferred to Radial Blankets
(No Moderation BOEC)

	<u>Power (MWth)</u>	<u>Percent</u>
Core	1321.71	87.51
Internal Blankets	92.51	6.16
Axial Blankets	24.25	1.61
Radial Blankets	70.53	4.72

Table 3
Power Generated by Various Parts of the Reactor with
Internal Blankets Transferred to Radial Blankets
(Moderation BOEC)

	<u>Power (MWth)</u>	<u>Percent</u>
Core	1306.84	87.12
Internal Blankets	93.33	6.23
Axial Blankets	23.97	1.59
Radial Blankets	75.86	5.07

The fraction of power generated by the radial blanket increases from 0.68% for the regular core (with a fresh radial blanket) to 4.72% for the unmoderated in-out shuffled radial blanket to 5.07% for the moderated in-out shuffled blanket. Comparing the case of the moderated blanket with the regular core/fresh blanket the difference in the power produced in the radial blankets is equal to the power generated by 97 fuel assemblies in the outer ring of the core. This implies that with this system of shuffling the size of the core can be

reduced by as much as 97 fuel assemblies, or 12.5%. In addition, there would be a reduction in (and perhaps elimination of) reprocessing requirements for the internal or radial blankets.

It should be noted that this "saving" must be viewed with respect to the loss of marketable plutonium bred in the internal and radial blanket assemblies. The net savings depends on the worth of this lost plutonium, and can only be found after a comparative fuel cycle economic analysis.

The future plans include a parallel analysis of the core and blanket fuel management for the case of thorium internal blankets, and performance of fuel cycle economic analyses for both cores.

References

1. Rogus, R.D., "Plutonium Production In Spectrum Softened Internal Blankets 22.901 Special Problem," M.I.T. Nuclear Engineering Department, April 1979.
2. Kidman, R. B. et al., "LIB-IV, A Library of Group Constants for Nuclear Reactor Calculations," Los Alamos Scientific Laboratory, LA-6260-MS (1976).
3. Hardie, R. W., et al., "1-DX-A One-Dimensional Diffusion Code for Generating Effective Nuclear Cross Sections," Battelle Memorial Institute, BNWL-954 (1969).
4. Little, W. W., et al., "2-DB-User Manual, Revision 1," Battelle Memorial Institute, BNWL-831 (1969).
5. Cappiello, M. W. and D. R. Marr, "LMFBR Design with the Composite Fuel Assembly," Transactions of American Nuclear Society, p. 608 (June 1978).

3. Administrative Matters

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

As of March 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

R. Rogus, Special Project Student, MIT Subject 22.901.

FAST REACTOR BLANKETS

RESTRICTIONS		CURRENT MONTH	FISCAL YEAR TO DATE	CUMULATIVE
EXPENDITURES		MARCH '79	AS OF 3/31/79	
SALARIES AND WAGES				
FAC SAL-TEN	13,359.00	604.44	4,382.23	10,004.45
SUMMER FACULTY-ON	15,581.00			
RESEARCH STAFF-ON	4,811.00		1,240.47	2,988.44
HOURLY PERSONNEL-ON	2,000.00	8.14	138.66	581.00
SECRETARIAL & CLERICAL-ON	2,365.00	120.00	969.83	2,569.58
EXEMPT-TECH-ON			1,487.27	12,710.36
TOTAL SUBJECT TO E. B.	38,116.00	732.58	8,218.46	28,853.83
GRADUATE STUDENT STAFF-ON			425.00	425.00
RESEARCH ASSISTANT-ON	28,770.00	1,920.00	10,800.00	17,960.00
MIT STUDENTS-ON			1,533.75	2,342.58
UNDERGRAD SALARIES-UROP				495.26
TOTAL SALARIES AND WAGES	66,886.00	2,652.58	20,977.21	50,076.67
EMPLOYEE BENEFITS ON OFF				
BILLING RATES 26.00% 30.00%	9,910.00	190.47	2,136.80	7,501.99
OPERATING EXPENSES				
TOTAL OPERATING EXPENSES	13,012.00	196.51	2,862.08	10,536.41
COMPUTATION EXPENSES				
E.D.P. EXPENSE		1,291.84	1,728.18	2,653.55
I.P.C. CHARGES	11,000.00	1,485.44	14,085.28	19,549.31
TOTAL COMPUTATION EXPENSES	11,000.00	2,777.28	15,813.46	22,202.86
INDIRECT EXPENSES ON OFF				
BILLING RATES 67.00% 15.00%	41,192.00	1,261.64	11,868.38	31,925.37
ADJ TO ACTUAL 66.00% 16.00%		18.83	177.15	177.15
TOTAL INDIRECT EXPENSES	41,192.00	1,242.81	11,691.23	31,748.22
TOTAL EXPENDITURES		7,059.65	53,480.78	122,066.15
UNEXPENDED BALANCE				27,529.55