COO-2250-9

MIT LMFBR BLANKET RESEARCH PROJECT

Principal Investigator
Michael J. Driscoll

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

April 1, 1974 - June 30, 1974

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Contract AT(11-1)-2250

Quarterly Progress Report

April 1, 1974 - June 30, 1974

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1. General

In accord with a request by the Chicago Operations Office (COO) this quarterly report is being written in advance of the end of the report period to facilitate administrative action related to FY 75 renewal. Thus some of the activities reported represent current projections of anticipated progress.

Also in accord with a COO request, document numbers will henceforth be assigned to quarterly reports, including the following retroactive designations:

COO-2250-6: MIT LMFBR Blanket Research Project, Quarterly Progress Report, July-September 1973.

COO-2250-7: MIT LMFBR Blanket Research Project, Quarterly Progress Report, October-December 1973

COO-2250-8: MIT LMFBR Blanket Research Project, Quarterly Progress Report, January 1, 1974 - March 31, 1974.

Likewise, in order to facilitate timely reporting of all technical and administrative progress the following additional changes will be implemented:

(a) A summary progress report on the preceding FY will be appended to the final Quarterly Report of the FY

(b) More topical reports will be issued as the work is completed: for example, covering some of the areas investigated by Engineer's and Master's Degree candidates, which were formerly not written up for AEC distribution until the annual report was prepared following the end of the FY. Work of this type not issued as topical reports will be given more extensive coverage in the Quarterly Reports. As in the past, the major tasks covered by PhD/ScD research will continue to be submitted as topical reports.

(c) A separate annual report will still be issued, but reduced in scope to reflect the greater reliance placed upon the more timely topical and quarterly reports.

* * *

The MIT Reactor has been shutdown to permit renovation starting May 24, 1974. Resumption of operations is currently scheduled for October 1, 1974.

P. Scheinert and M.J. Driscoll participated in an RRD review meeting on gamma-ray heating measurement techniques held at AEC headquarters on April 23, 1974.

2. Spectrum Measurements

Work continues on the development of the multiple-foil stack method for neutron spectrum determination in the epithermal energy range.

The theoretical analysis has been completed, and several significant differences identified between the present approach and earlier work by Nisle [1]:

(a) In ANCR-1066 the case involving an isotropic surface source is analyzed; in the present work an isotropic volume source is treated.

(b) In ANCR-1066 the same fine group cross sections are used for each foil in the stack, corresponding to the use of infinitely dilute resonance integrals; in the present work the integration is carried out numerically (instead of analytically as in ANCR-1066) to treat the transmission of neutrons through individual foils, including doppler broadening of the resonances.

(c) In ANCR-1066 the gross foil activity is employed in the unfolding process; in the present work we will also treat the case in which the difference between surface and central foil activities is analyzed since this will provide data sensitive only to strong resonance absorption, and thereby emphasize the epithermal region of the neutron spectrum.

Experimental work has been completed: three gold foil stacks have been irradiated and the data analyzed: two runs in blanket Mockup No. 4, one bare and the other cadmium-covered; and one run in an 1/E spectrum for calibration purposes. Each stack consisted of approximately 100 foils, each 0.5 to 2.0 mils thick. The computer program required to generate cross sections from ENDFB data has been written and is being debugged: current work is focused on verification that the code will yield correct results in cases for which an analytic solution is known, such as that involving infinitesimally thin foils. Simulated data has been processed with the MIT version of the SPECTRA unfolding program, but the results are so far inconclusive: it is not yet clear that we can merely use spectrum unfolding programs developed for multiple-foil activation data for single-material foil-stack data.

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[1] R.G. Nisle and Y.D. Harker, "Self-Shielding in Stacked Foils," ANCR-1066, Nov. 1972.

During the coming quarter work will be concentrated on debugging the various computer programs required to process the data. A final conclusion on the efficacy of this approach will be made by October 1, 1974.

3. Gamma Heating

Experimental work using TLD and ion-chamber/dosimeter (ICD) detectors has been completed, as has calibration of all detectors using a Co-60 source. The results are shown in Fig. 1, in which the TLD, ICD and calculated heating traverses through Mockup No. 4 in stainless steel are compared. The calculations were made using the ANISN program in the S_8, P_1 option using an ORNL coupled n-γ cross section set (22 neutron, 18 gamma groups). Work is continuing to refine both the data analysis and the calculations. A topical report on the experimental work will be issued by October 1, 1974.

The only other experimental method under active consideration at present involves use of the RPL effect. While we concur with the consensus opinion at the RRD meeting of March 23, 1974 that RPL glasses offer no particular advantage over TLD's as dosimeters for gamma heating measurements, one aspect of RPL dosimetry is being investigated further. In reference 1 it is indicated that LiF TLD's also exhibit an RPL effect. During the coming quarter we will investigate whether RPL readout of our LiF TLD's can be employed as a supplementary means of data acquisition.

4. U-238 Self Shielding

Experimental traverses of U-238 in-rod absorption near the blanket/reflector interface have been completed. Figure 2 shows a typical result. The large increase in capture rate at the interface due to decreased self-shielding is evident.

During the reactor shutdown, work will be concentrated on completion of the theoretical and numerical methods necessary to account for this phenomenon in LMFBR design calculations.

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[1] D.F. Regulla, "Lithium Fluoride Dosimetry Based on Radiophotoluminescence," Health Physics, 22, 491, 1972.

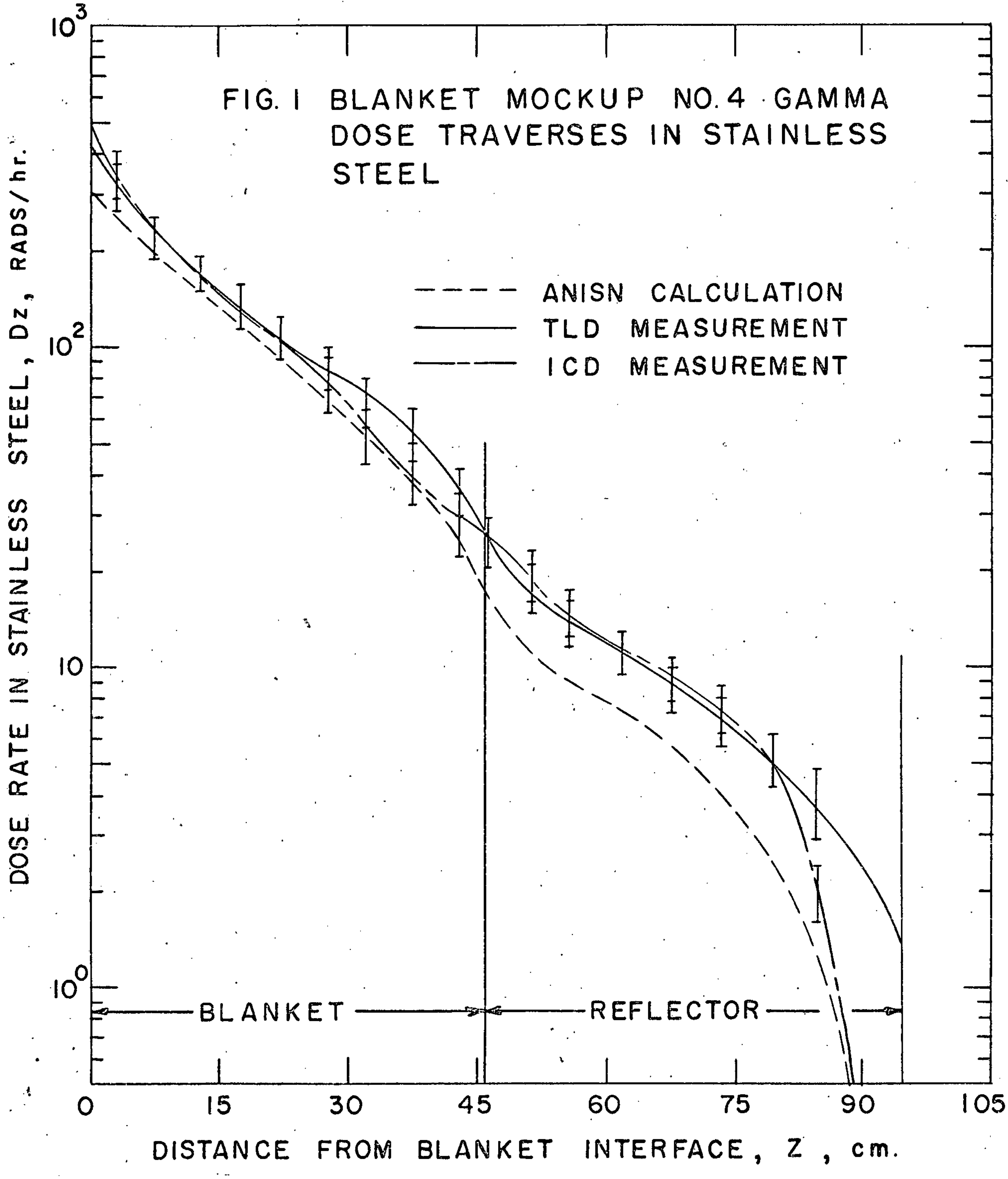


FIG. I BLANKET MOCKUP NO.4 GAMMA DOSE TRAVERSES IN STAINLESS STEEL
ANISN CALCULATION
TLD MEASUREMENT
ICD MEASUREMENT
BLANKET
REFLECTOR
DOSE RATE IN STAINLESS STEEL, Dz, RADS/hr.
DISTANCE FROM BLANKET INTERFACE, Z, cm.
10^3
10^2
10
10^0
0
15
30
45
60
75
90
105

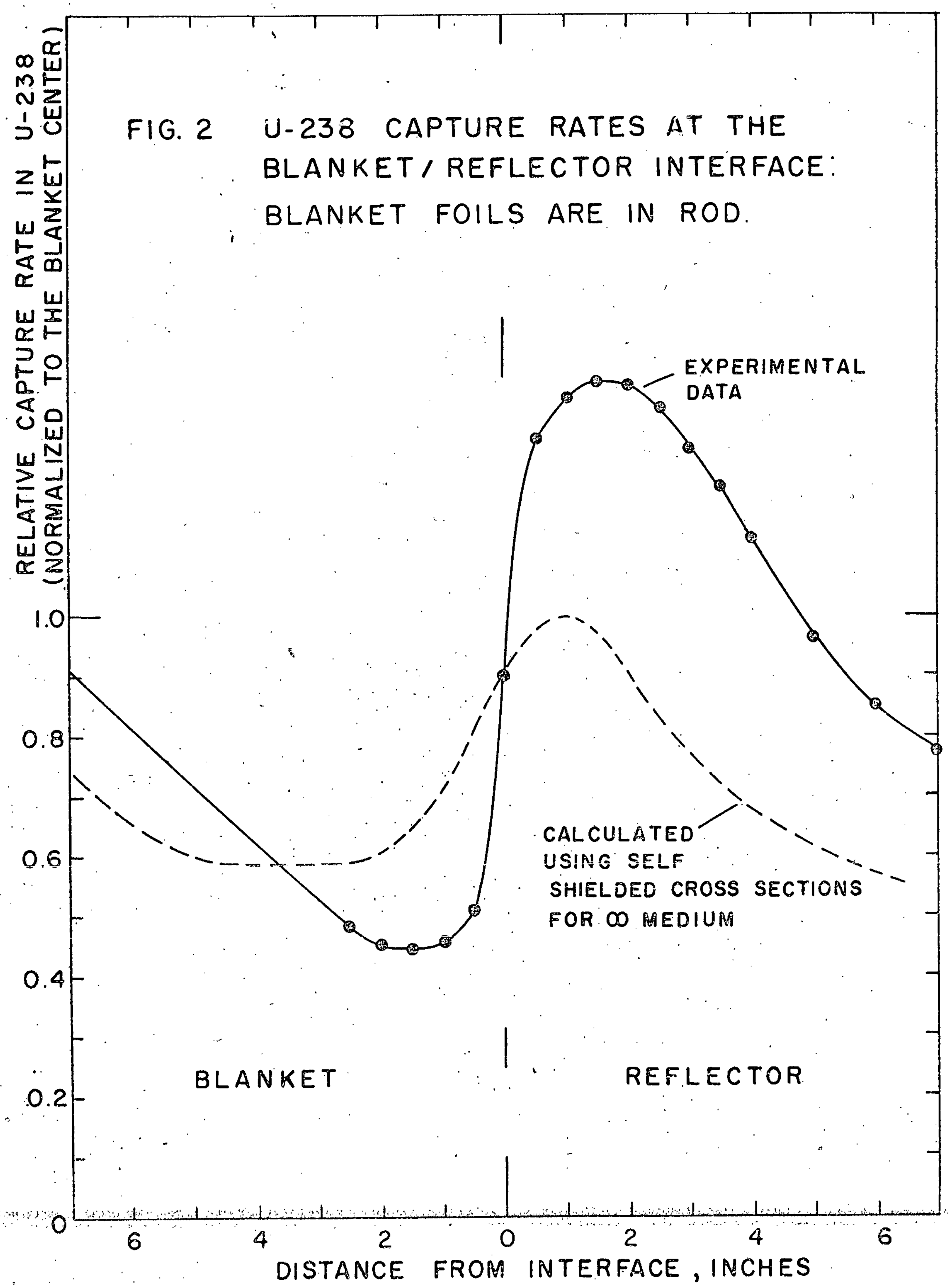


FIG. 2 U-238 CAPTURE RATES AT THE BLANKET/REFLECTOR INTERFACE: BLANKET FOILS ARE IN ROD.
RELATIVE CAPTURE RATE IN U-238 (NORMALIZED TO THE BLANKET CENTER)
EXPERIMENTAL DATA
CALCULATED USING SELF SHIELDED CROSS SECTIONS FOR ∞ MEDIUM
BLANKET
REFLECTOR
1.0
0.8
0.6
0.4
0.2
0
6
4
2
0
2
4
6
DISTANCE FROM INTERFACE, INCHES

5. Blanket Performance Calculations

The change in radial blanket performance as reactor core size is increased is being investigated. Multigroup calculations, using 4-group region-wise cross section sets, are being carried out using the 2DB code, and the results evaluated using correlations suggested by a simple one group analysis. The effect of substituting a nickel reflector for the radial blanket is also being investigated.

Figure 3 shows the variation of radial blanket breeding ratio with core size: the agreement of the single-region core results with the theoretical results (decrease as $(R+\delta)^2$), and simular good agreement of the power-flattened (multizone) core calculations with the predicted R^{-1} dependence are evident.

Figure 4 shows the percent savings in core critical mass achieved by replacing the radial blanket with a nickel reflcetor: the 1-region core data follows the theoretically predicted R^{-3} dependence, and the multizone data agrees with the R^{-1} dependence predicted by the simple one-group power-flattened model.

This work has now reached the point where systematic economic analyses are practical to determine whether a point is reached where radial blankets become uneconomic. It is already clear from the above results that significant differences are to be expected between such results and any previously reached on the basis of one region core analysis.

* * *

A minor effort is being carried out under partial project support to determine whether higher order perturbation calculations can be used to calculate blanket burnup effects. To date work has been focused on debugging of the computer programs required. Completion is scheduled by September 1, 1974.

6. Personnel

Staff

M.J. Driscoll
D.D. Lanning
I. Kaplan

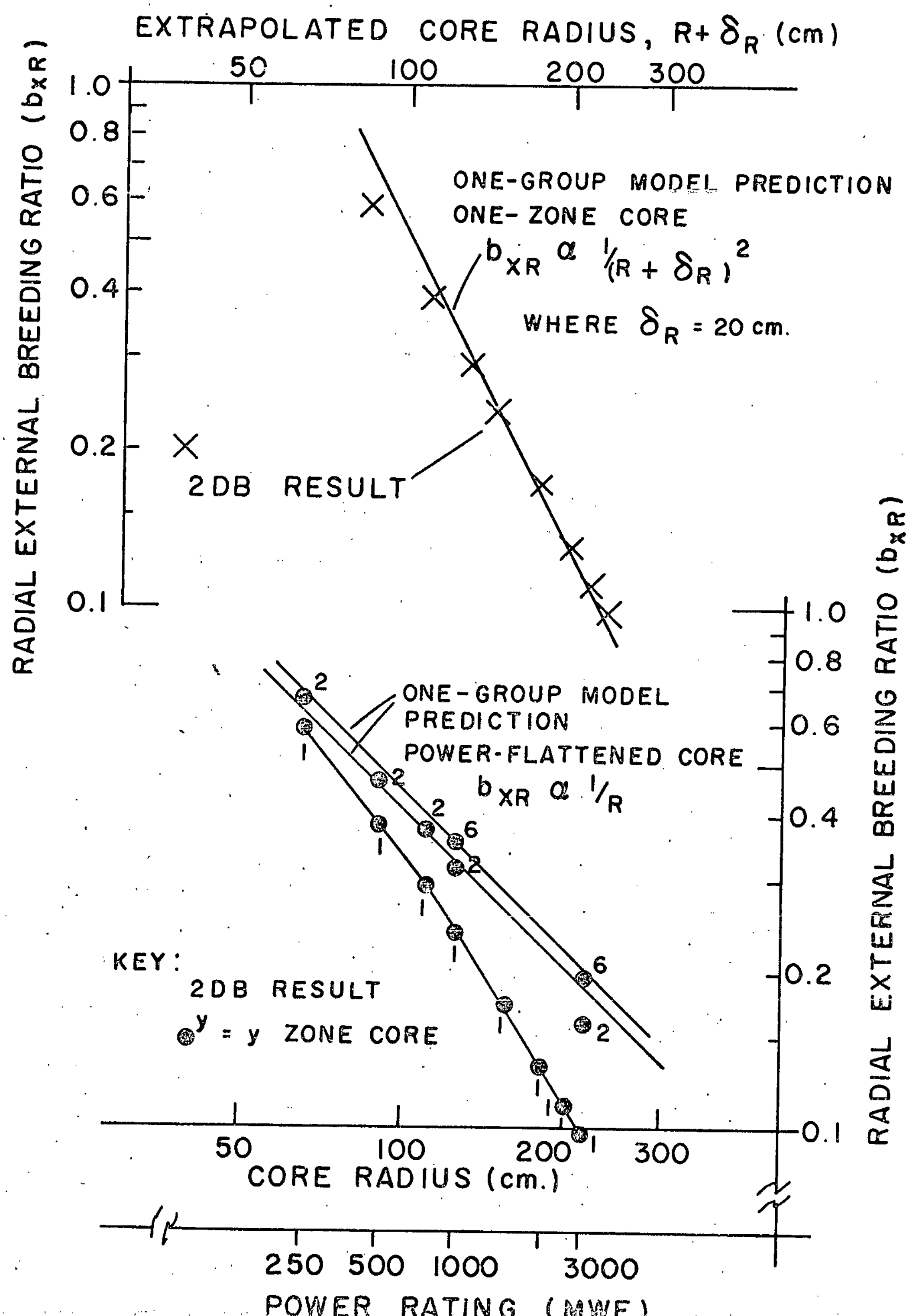
Engineering Assistant

A.T. Supple

Computer Operations Assistant

V.A. Miethe

FIG. 3 THE EFFECT OF CORE-RADIUS AND ZONE-NUMBER ON RADIAL EXTERNAL BREEDING RATIO



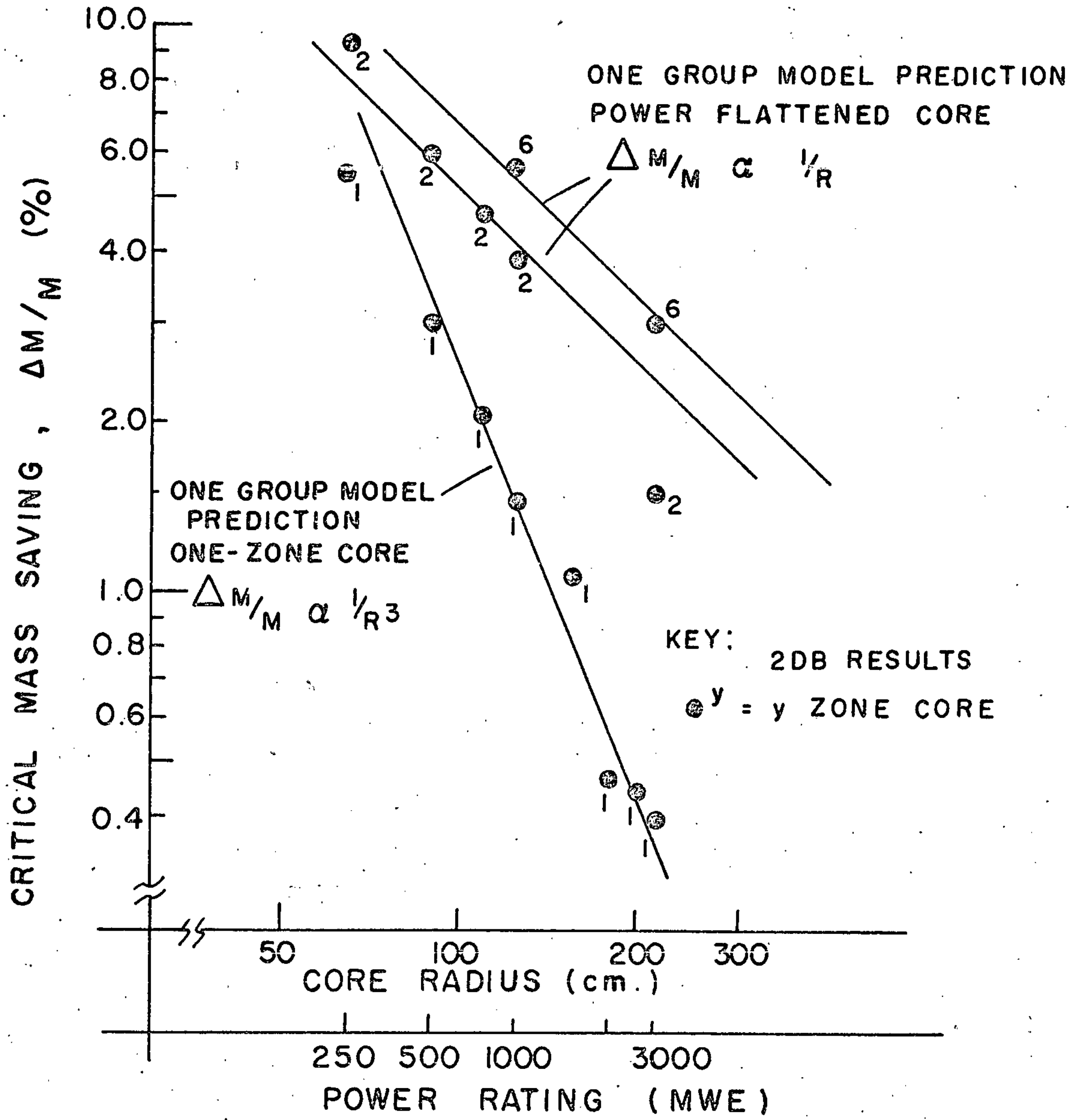


FIG. 4 THE EFFECT OF CORE-RADIUS AND ZONE-NUMBER ON CRITICAL MASS SAVINGS DUE TO NICKEL RADIAL REFLECTOR USE

Students

O. Kadiroglu, ScD Student, Research Assistant; working on self shielding calculations and measurements.

M. Kalra, ScD Student, Research Assistant; working on gamma transport and gamma heating calculations.

P. Scheinert; Engineer's Degree Student, Research Assistant; working on gamma heating measurements

J. Shin, Laboratory Assistant; working on gamma heating measurements

A. Tagishi, ScD Student, Research Assistant; working on blanket performance analysis.

M. Yeung, SM Student; working on the foil stack method for epithermal neutron spectrometry.

A. Leveckis, Undergraduate Lab. Assistant (until May 15, 1974).

R. Masterson, SM Student; working on application of perturbation methods to blanket burnup calculations

Attachment No. 1

Summary Progress Report for FY 1974

1. Foreword

As in the past, a detailed Annual Progress Report will be prepared for FY 1974. This highly abbreviated version has been drafted to facilitate contract review.

During the past FY work was carried out in the following areas:

(a) Acquisition of benchmark data on Blanket Mockup No. 4.

(b) Acquisition, evaluation and application of gamma heating methods.

(c) Investigation of advanced blanket configurations.

Each of these areas is discussed in more detail in the following sections of this report.

2. Benchmark Data

The most important undertaking during the past year has been the completion of foil activation measurements on Blanket Mockup No. 4, a three-subassembly-row, steel-reflected blanket driven by a simulated demonstration-reactor-sized core. This work consisted chiefly of the following:

(a) Foil activation traverses through the core and reflector, including detailed traverses at the blanket/reflector interface, for such important reactions as U-238 capture and U-238, U-235 and Pu-239 fission

(b) Neutron spectrum determination in the blanket using foil activation techniques. Work was completed on a mixed-powder multiple-foil method: the results indicated that the sub-kev spectrum is probably harder (i.e., fewer neutrons) than calculated. Work is underway on a variation of the sandwich foil and foil stack methods, again to determine epithermal neutron spectra. Foil irradiations have been completed and completion of analytical and numerical work is scheduled for the first quarter of FY 1975.

(c) Fast neutron penetration in the reflector. Neutron spectrum and threshold detector traverses were made to investigate previously noted "anomalously high fast neutron penetration": it was concluded that the prior results are probably due to neglect of such factors as sub-threshold fission in the U-238 detectors employed. Further work in this area is planned for Mockup No. 5 in FY 1975.

Finally, it is possible to formulate the blanket breeding ratio as the product of three terms: the first characteristic only of the core, the second coupling the core to the blanket, and the third characteristic only of the blanket. All three are amenable to experimental measurement, the key input parameters are chiefly fission integral ratios. In the blanket the controlling term is the ratio of U-238 capture to fission integrals. Work is underway to analyze Mockup No. 4 data in terms of this model, and it is hoped that this approach will permit a definitive confirmation of blanket breeding performance calculations.

3. Gamma Heating Methods

During FY 1974 the major effort under this task involved acquisition, evaluation and application of state-of-the-art methods for measuring gamma heating in the blanket and reflector regions of fast reactor blankets. The following major accomplishments are noted:

(a) Thermoluminescent dosimeter (TLD) measurements were completed in Blanket Mockup No. 4 and compared to measurements made with miniature ionization chambers operated in the dosimeter mode (ICD). Data has been obtained using various sleeve materials encapsulating the TLD's: lead (to simulate UO_2), aluminum (to simulate sodium) and stainless steel. The results agree within their respective experimental uncertainties, but the measured data is higher than that calculated using state-of-the-art computational methods (coupled n-γ, S_N calculations). For future work it is concluded that TLD's offer the best combination of features.

(b) Radiophotoluminescent (RPL) detectors have also been looked into. Although it was concluded that RPL glasses offer no substantial advantage over TLD's for the present applications this method will be pursued further along one promising line: it has been reported in the literature that LiF TLD's also exhibit an RPL effect and therefore it may be possible to use an RPL readout device to obtain supplementary data from routine TLD measurements. This work will continue through the first quarter of FY 1975, having been delayed somewhat by the inability of the AEC to provide equipment funds under the current contract, which requires in-house construction of the detection system.

(c) A Co-60 calibration facility for TLD, ICD and RPL dosimeters has been constructed for use by project researchers.

(d) In parallel with the experimental effort, an evaluation of gamma heating calculations is being carried out to identify the simplest possible methodology yielding adequate precision in the LMFBR blanket and adjacent reflector, and to identify the causes of the discrepancies between measurements and calculations. It appears for example that P_1 calculations using as few as 3 gamma groups are adequate. This work will continue through FY 1975.

(e) The RESPOND program for relating TLD readout data to heating rate has been made operative at MIT and several improvements incorporated. Careful review of the theoretical basis upon which these calculations are carried out is being conducted; the work is being coordinated with a parallel effort at ANL. At the present time the lack of a completely validated theoretical interpretation is one of the few remaining obstacles to universal acceptance of TLD's for gamma heating measurements.

(f) An interesting approach to measurement of gamma spectra has been attempted: TLD's sheathed in a variety of different materials are used in a manner totally analogous to the multiple-foil method for neutron spectrometry. Results obtained to date have been encouraging and the measurements indicate that measured spectra have fewer high and low energy gammas than calculated -- a result consistent with spectral index traverses (ratios of doses in different sleeve materials: e.g., Al/Pb).

4. Blanket Analysis

Significant progress was made in this area, culminating in the release of three topical reports:

(a) P.J. Wood and M.J. Driscoll, "Assessment of Thorium Blankets for Fast Breeder Reactors," COO-2250-2, MITNE-148, July 1973.

(b) 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.

(c) G.J. Brown and M.J. Driscoll, "Evaluation of High Performance LMFBR Blanket Configurations," COO-2250-4, MITNE-150, May 1974.

The following major conclusions are supported by the analyses documented in these reports:

MITNE-148:

(a) Under current economic conditions the use of thorium in place of uranium in fast reactor blankets could reduce LMFBR fuel cycle costs by on the order of 50% due to the premium value of U-233 as thermal reactor fuel.

(b) Detailed analysis of the neutronic problems associated with the change from uranium to thorium blankets showed that most were negligible, and that, with an only moderate degree of foresight a reactor could be designed to accomodate either fertile species.

(c) A simple economic parameter was developed to characterize the effect of the economic environment on blanket design and fuel management strategy, and simple correlations developed between this parameter and optimum blanket irradiation time and discharged fuel enrichments.

MITNE-157:

(a) A totally internal blanket inserted at the center of a fast reactor has many attractive features, the most important of which are probably the lower radiation induced swelling and bowing characteristics of this concept, the so-called parfait blanket.

(b) Other advantages include decreased burnup reactivity swing, slightly larger breeding ratio and slightly lower peak power density; disadvantages include a slightly higher core fissile inventory and slightly reduced Doppler reactivity coefficient.

MITNE-150

(a) The use of graphite reflectors for LMFBR blankets was shown to be an economically desirable development.

(b) The economic penalty due to blanket overcooling was quantified in the form of a simple analytic model which permits comparison of various blanket design and fuel management alternatives. While fuel management savings between alternatives tend to be on the order of 10^5 \$/yr., the overcooling charges tend to be 5-10× larger, and are therefore an essential part of any design comparison of alternative blankets or blanket fuel management schemes.

(c) Blanket seeding with fissile material to ameliorate the steep radial power gradient does not appear to be economically justifiable considering fuel cycle or overcooling costs.

The above results and reports constitute essentially all of this category of analysis planned under the current contract. The sole remaining question being investigated has to do with the economic viability of the radial blanket as core size is increased. In the past it has been intimated that a good reflector might be preferable over a breeding blanket in very large cores. To date the neutronic analysis in this area has shown that substantially different results are obtained if one analyzes power-flattened as opposed to single-zone cores, and the former (and more realistic) case favors the radial blanket more than does the latter. Thus if there is a crossover point it will come at larger core sizes than previously predicted. During the coming FY the requisite economic analysis will be carried out to quantify these conclusions.

5. Future Work

During FY 1975 the following work is planned:

(a) Return the Blanket Test Facility to operation as soon as possible following completion of MIT Reactor renovation: the current estimated startup date is October 1, 1974.

(b) Install Blanket Mockup No. 5, which will differ from Number 4 primarily in the use of more realistic reflector assemblies which are also better suited for planned experiments.

(c) Carry out a series of foil activation and gamma heating traverses, with primary emphasis on the reflector region and on areas in which the greatest discrepancies between prior experiments and calculations have occurred: such as threshold foil traverses.

(d) Complete compilation of, and issue, a benchmark problem organized around Blanket Mockup No. 4.

(e) Complete and issue topical reports on gamma heating measurements, on gamma heating calculations, on resonance self shielding near interfaces, and on the economic prospects of the blanket region as core size is increased.