UNCLASSIFIED

OFFICIAL USE ONLY

BNWL-762

FAST FLUX
TEST FACILITY
PROJECT REPORT

5-

EVALUATION OF NPTR/FTR
NEUTRONICS DIFFERENCES

Q. L. Baird
S. L. Engstrom

April 1968

AEC RESEARCH &
DEVELOPMENT REPORT

OFFICIAL USE ONLY

UNCLASSIFIED

BATTELLE NORTHWEST
BATTELLE MEMORIAL INSTITUTE PACIFIC NORTHWEST LABORATORY
POST OFFICE BOX 999 / RICHLAND, WASHINGTON 98352

BNWL-762

INFORMATION CONCERNING USE OF THIS REPORT

PATENT STATUS

This document copy, since it is transmitted in advance of patent clearance, is made available in confidence solely for use in performance of work under contracts with the U. S. Atomic Energy Commission. This document is not to be published nor its contents either disseminated or used for purposes other than specified above before patent clearance for such use has been secured, upon request, from the Chief, Chicago Patent Group, U. S. Atomic Energy Commission, 9800 So. Cass Ave., Argonne, Illinois.

PRELIMINARY REPORT

This report contains information of a preliminary nature prepared in the course of work under Atomic Energy Commission Contract AT(45-1)-1830. This information is subject to correction or modification upon the collection and evaluation of additional data.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

PACIFIC NORTHWEST LABORATORY

RICHLAND, WASHINGTON

operated by

BATTELLE MEMORIAL INSTITUTE

for the

UNITED STATES ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(45-1)-1830

PRINTED BY/FOR THE U.S. ATOMIC ENERGY COMMISSION

84-1950-016 (11-67)

XERO-R1 RICHLAND, WASH

UNCLASSIFIED

BNWL-762

3 3679 00061 3291

EVALUATION OF NPTR/FTR NEUTRONICS DIFFERENCES

April 8, 1968

Prepared by

Q. L. Baird
S. L. Engstrom

Approved by

P. L. Hofmann

PACIFIC NORTHWEST LABORATORY
Richland, Washington 99352
Operated by
Battelle Memorial Institute
for the

U. S. Atomic Energy Commission under Contract No. AT(45-1)-1830

UNCLASSIFIED

EVALUATION OF NPTR/FTR NEUTRONICS DIFFERENCES

S. L. Engstrom and Q. L. Baird

INTRODUCTION

A primary design requirement of the NPTR is that it provide the closest practicable reproduction of the FTR neutronics characteristics. It is the purpose of this document to describe the degree to which the simulation has been accomplished in the reference design of the NPTR. An investigation of the simulation afforded by alternate design features has also been made and is reported here.

The NPTR will operate at a temperature well below the shutdown and operating temperatures of the FTR. It is important, therefore, to establish the relative importance of simulating the effects of temperature on the system.

The adequacy of the simulation achieved can best be assessed by observing the effects of the residual differences on the reactor physics parameters of primary importance. A number of parameters have been selected for use in the role of sensors for this purpose. The neutron flux spectrum and the k_{eff} of the system were selected as excellent general indicators of system changes. The impact of spectral changes can be illustrated by looking at the variation of parameters such as the Doppler coefficient, and the reaction rates for ^{239}Pu fission and boron absorption. The differences in reactivity worths (for fuel and poison) as calculated for an FTR system and a NPTR system are also considered to be important sensors.

In order to compare the neutronics characteristics of the FTR and the NPTR (reference core and various alternate features) a choice of calculational

techniques and models was made which were considered to be the simplest available but yet adequate for an unambiguous evaluation of differences.

DESCRIPTION OF CALCULATIONS AND RESULTS

Values of the selected sensor parameters for four different models of an NPTR are compared to similar values for an FTR. Each of these models has NPTR fuel modules that contain a complete FTR-like fuel subassembly as well as all the coolant and stagnant sodium associated with the fuel. Structural details of these modules introduce a 2.17 v/o void⁽¹⁾ and displace a corresponding volume of sodium. The remaining differences from the FTR for each design are:

1. NPTR (Al) - differs in composition from the FTR in that
Al guide tubes are used with about 25% of the
fuel pins. The Al tubes displace Na and
stainless steel wire wraps.
2. NPTR (SS) - differs from the FTR as in case (1) except
the guide tubes are made of SS rather than
Al.
3. NPTR (NaK) - This design has the Al guide tubes, as in
(1), but the total Na content is replaced
by NaK.
4. NPTR (Molten Na) - differs from the FTR only in that the
NPTR fuel module is still used, and it contains
lower temperature sodium.

These four NPTR alternates were compared with the FTR base case using 26 group FCC calculations. This code assumes an infinite homogeneous medium and uses fundamental mode diffusion theory to calculate k effective. The same

buckling was used for all cases. In order to accentuate differences in k_{eff} (a conservative calculational approach), the homogeneous subassembly contents rather than the homogenized core contents were used for these calculations. As a result, the calculations are for a higher fuel to Na ratio and consequently a somewhat lower Doppler coefficient is calculated than that resulting from a more dilute FTR case. The compositions, reactivity discrepancies, and Doppler coefficients for the four NPTR models and the FTR base case are listed in Table I.

The FTR spectrum is shown in Figure 1. Plots of the differences between three of the NPTR alternates and the FTR spectrum are shown in Figure 2-4. Figure 5 compares spectra of the FTR at 300°K and at 600°K. It will be noted that there is very little change in the spectrum above 1 keV. To understand the importance of the differences below 1 keV, a number of calculational sensors have been employed. The fraction of the flux below 1 keV is in fact very small for all the cores considered. This is shown in Table I. Reaction rates, by energy group, for the core centers have been calculated for ^{239}Pu $v\Sigma_f$ as well as ^{10}B absorption. Figures 6-11 present a comparison of these reaction rates for the various NPTR alternates with the reaction rates for the FTR.

Several other calculations were made, using the FCC code, to isolate reactivity changes associated with compositional and temperature changes. Of particular interest to the FTR/NPTR equivalence studies is the Na void coefficient. It was found that an increase in sodium temperature of the NPTR from 300°K to 400°K, which reduces the Na density from .950 to .921; results in a change in k_{eff} of $-.00082$.

A study was also made to determine the effect of operating temperature on the worth of a fuel subassembly and a reactivity control rod (typical of the FTR). The analysis of these differences in an FTR-like system was made

Table I

FTR/NPTR Comparison

<u>Subassembly</u>	<u>600°K FTR</u>	<u>300°K NPTR (Al)</u>	<u>300°K NPTR (SS)</u>	<u>300°K NPTR (NaK)</u>	<u>400°K NPTR (Molten Na)</u>
<u>Vol. Fractions</u>					
PuO ₂	.07623	.07623	.07623	.07623	.07623
UO ₂	.27576	.27576	.27576	.27576	.27576
SS	.24587	.23973	.33815	.23973	.24587
Na	.33999	.22601	.22601	.1356	.31829
Al		.09842		.09842	
K				.09041	
Void	.06215	.08385	.08385	.08385	.08385
<u>Δk*</u>		+.01004	+.01469	+.00254	+.00019
<u>Doppler Constant</u>					
(U ²³⁸ -2100°K)	-.00314	-.00349		-.00309	-.00318
<u>Fraction of Flux above 1 keV</u>	.9959	.9955	.9951	.9964	.9957

*Δk = k_{eff}, NPTR - k_{eff}, FTR

using the 1-D transport code DTF-IV, in cylindrical geometry with the S-4 approximation and a 26 group cross section set. The cross sections, averaged over zone compositions in FCC also reflect the neutronics effects of the operating temperatures involved. The two cases being compared are the FTR at 600°K and at 300°K. Only the Na atom densities for the two cases are changed to reflect its thermal expansion. Fuel expansion effects are not simulated. Table II is a list of these worths.

DISCUSSION AND CONCLUSIONS

As would be expected, the molten sodium model of the NPTR demonstrates the greatest degree of equivalence to the FTR. However, it is of interest to note that all of the models achieve a remarkably good replication of FTR conditions. It is also evident from the k_{eff} value that the use of aluminum guide tubes leads to closer simulation than does the stainless steel. While fuel density aluminum, as used for the guide tubes, makes a fairly good sodium simulant, the use of NaK in conjunction with them has the obvious effect of bringing the diluent atom density to a value nearer to that in the FTR.

Both the frozen sodium and NaK models have their greatest departure from the FTR spectrum in the region of the sodium absorption resonance at 3 keV. As the reaction rates indicate, however, this is not a serious departure. The small changes in Doppler coefficient and k_{eff} also support this assertion. The reference and alternates are each considered to be suitable simulations of the FTR on the basis of the sensors which have been compared.

Table II

FTR/NPIT Temperature Equivalences

CALCULATION DESCRIPTION	WORTH Δk
Temperature Defect (less fuel expansion component)	.00664
Worth of Fuel S/A, 300°K	.00942
Worth of Fuel S/A, 600°K	.00954
Worth B ₄ C Rod, 300°K	.01620
Worth B ₄ C Rod, 600°K	.01525

The comparative worth values for fuel and poison shown in Table II indicate a very weak dependence on temperature. The fuel subassembly worths change by only 1.3% between the two temperatures and the poison rod by only 6.2%. Since the temperature difference for these two cases was 300°C it is quite obvious that even a moderate effort to simulate the temperature effects would be quite satisfactory. Measured values for even the extreme ΔT would be quite amenable to empirical correction and could be correlated with confidence. Thus, it is apparent that exact simulation of FTR temperature is not a rigorous requirement for the NPTR.

Figure 1. FTR Spectrum 600° K

Figure 2. Spectral Difference 300° K. NPTR (A1) - 600°K. FTR

Figure 3. Spectral Difference 400°K. NPTR (Molten Na) - 600° K. FTR

Figure 4. Spectral Difference 300°K. NPTR (NaK) -600°K. FTR

Figure 5. Spectral Difference 300°K. FTR -600°K. FTR

Figure 6. ^{239}Pu Reaction Rate — 300°K NPTR (AI) --- 600°K FTR

Figure 7. ^{239}Pu Reaction Rate — 300°K NPTR (Molten Na) --- 600°K FTR

Figure 8. ^{239}Pu Reaction Rate — 300°K (NaK) --- 600°K FTR

Figure 9. ^{10}B Absorption Rate — 300°K. NPTR (AI) --- 600°K FTR

Figure 10. ^{10}B Absorption Rate — 400°K. NPTR (Molten Na) --- 600°K FTR

Figure 11. ^{10}B Absorption Rate — 300°K NPTR (NaK) --- 600°K FTR

- 30 U. S. Atomic Energy Commission
Division of Reactor Dev & Tech
Washington, D. C. 20545
M Shaw, Director, RDT
Asst Dir for Nuclear Safety
Analysis & Evaluation Br, RDT:NS
Environmental & Sanitary Engrg
Br, RDT:NS
Research & Development Br, RDT:NS
Asst Dir for Plant Engrg, RDT
Applications & Facilities Br, RDT:PE
Components Br, RDT:PE
Instrumentation & Control Br, RDT:PE
Systems Engineering Br, RDT:PE
Asst Dir for Program Analysis, RDT
Asst Dir for Project Mgmt, RDT
Liquid Metals Projects Br, RDT:PM
FFTF Project Manager, RDT:PM(3)
Asst Dir for Reactor Engrg
Control Mechanisms Br, RDT:RE
Core Design Br, RDT:RE (2)
Fuel Fabrications Br, RDT:RE
Fuel Handling Br, RDT:RE
Reactor Vessels Br, RDT:RE
Asst Dir for Reactor Tech
Chemistry & Chemical Separations
Br, RDT:RT (2)
Fuels & Materials Br, RDT:RT
Reactor Physics Br, RDT:RT
Special Technology Br, RDT:RT
Asst Dir for Engrg Standards
- 1 AEC Idaho Operations Office
Nuclear Technology Division
CW Bills, Director
P. O. Box 2108
Idaho Falls, Idaho 83101
- 3 AEC Richland Operations Office
FFTF Program
JM Shivley
Federal Building
Richland, Washington 99352
- 1 San Francisco Operations Office
Director, Reactor Division
2111 Bancroft Way
Berkeley, California 94704
- 4 AEC, RDT Site Representative
Pacific Northwest Laboratories
PG Holsted (2)
LR Lucas
AD Toth
P. O. Box 550
Richland, Washington 99352
- 4 AEC, RDT Site Representatives
Atomics International
P. O. Box 591
Canoga Park, Calif. 91305

Argonne National Laboratory
9800 South Cass Avenue
Argonne, Illinois 60439

Atomic Power Development Asso
1911 First Street
Detroit, Michigan 48226

General Electric Co.
310 DeGuigne Drive
Sunnyvale, California 94086
- 1 Argonne National Laboratory
LMFBR Program Office
9700 South Cass Avenue
Argonne, Illinois 60410

43 Battelle-Northwest

SO Arneson
ER Astley
QL Baird
JM Batch - 328
RA Bennett
DC Boyd
CL Brown - 209E
CA Burgess
BA Chandler
TT Claudson - 326
PD Cohn - 3702
DL Condotta
DR Doman
RV Dulin
SL Engstrom
LM Finch
VW Gustafson - FB
JP Hale
KM Harmon
RA Harvey
BR Hayward - 308
RJ Hennig
GM Hesson
CW Higby
PL Hofmann
EM Johnston
DD Lanning - ROB
CW Lindenmeier
WW Little
JW Mitchell
CA Munro
RE Peterson
HCF Ripfel
WE Roake - 308
DW Shannon (2) - 324
DE Simpson
MO Slater
DD Stepnewski
KG Toyoda
RC Walker
FW Woodfield
FFTF File (2)
Tech Info (5)