AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

WSRC-TR-91-430

**NUCLEAR REACTOR TECHNOLOGY
AND SCIENTIFIC COMPUTATIONS**

KEY WORDS: Diffusion Theory
Analytical Solutions
Benchmarking
Transient

RETENTION PERIOD: PERMANENT

**VERIFICATION, VALIDATION, AND
BENCHMARKING REPORT FOR
AXLIB4: A Processor to Generate JOSHUA
Records of Axial Power Shape versus Time (U)**

By

T. T. Le

ISSUED: JULY 1991

**WESTINGHOUSE SAVANNAH RIVER COMPANY
SAVANNAH RIVER LABORATORY
AIKEN, SC 29808**

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT DE-AC09 89SR18035

PROJECT: **PHYSICS CODE CERTIFICATION**

TASK: **CERTIFICATION OF AXLIB4**

DOCUMENT: **WSRC-TR-91-430**

TITLE: **VERIFICATION, VALIDATION, AND BENCHMARKING
REPORT FOR AXLIB4: A Processor to Generate JOSHUA
Records of Axial Power Shape versus Time (U)**

APPROVALS

Christa Boman DATE: 12/6/91
C. BOMAN, TECHNICAL REVIEWER

C. E. Apperson DATE: 1-20-92
C. E. APPERSON, MANAGER
REACTOR PHYSICS GROUP

M. R. Buckner DATE: 1-20-92
M. R. BUCKNER, MANAGER
SCIENTIFIC COMPUTATIONS SECTION

Table of Contents

TABLE OF CONTENTS

	P a g e
Table of Contents.....	1
Summary.....	3
I. Introduction to AXLIB4.....	3
II. Verification.....	5
III. Validation.....	5
IV. Benchmark Problems.....	6
IV.1. Heterogeneous Static Benchmark Problem.....	6
4.1.1. Total and Decay Heat Power versus Time.....	6
4.1.2. Analytical Solution of Power Shape.....	8
IV.2. Homogeneous Time Dependent Benchmark Problem.....	13
4.2.1. Analytical Solution of the Initial Power Shape.....	14
4.2.2. Time Dependent Solutions.....	18
V. Conclusions.....	23
Appendix A: Data & Results for Problem 1.....	24
A.1. Geometry.....	24
A.2. Physics Data.....	24
A.3. Results.....	28
Appendix B: Data & Results for Problem 2.....	36

WSRC-TR-91-430

July 1991

Page 2 of 44

Table of Contents

B.1. Geometry	36
B.2. Physics Data	36
B.3. Results	36
References	44

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

SUMMARY

AXLIB4 is a transient one-dimensional diffusion theory calculation written to provide JOSHUA records of assembly axial power shapes versus time at start and end of subcycle while safety rods are falling during a scram. The WIGGLE¹ program written by R. E. Pevey provides the diffusion theory calculation. AXLIB4 is not a stand-alone code and is connected to LLAP² through an EXECUTE statement and JOSHUA interface libraries. The input data are passed to AXLIB4 from a driver routine (LLAP) and from interface JOSHUA records linking the code to the driver routine database.

This report concerns the verification and validation of AXLIB4. The verification was performed to determine if AXLIB4 was using the correct theory and that all the subroutines function as required. The validation was performed by comparing the results of the code with the analytical solutions of test problems. The first test problem is a heterogeneous calculation using a pre-accident power profile (includes end-fittings); this problem is designed to test the calculation of total and decay heat assembly powers input versus time, and the initial power shape calculation. The second test problem is a homogeneous problem designed to test the initial and transient power shape calculational ability. These two test problems and their analytical solutions are repeated from the Benchmarking Report for WIGGLE³ written by R. E. Pevey.

Since the results of these two benchmark solutions were identical to the analytical solutions, it is the conclusion of this study that AXLIB4 was correctly implemented and is ready to submit to SCMS.

I. INTRODUCTION TO AXLIB4

AXLIB4 is a one-dimensional, two-energy-group, six-delayed-neutron-precursor diffusion theory calculation which was written to provide JOSHUA records of assembly axial power shapes versus time at start and end of subcycle, that is, the libraries of Z^n terms in the equations in Section 2.2.2 of Reference 4. The calculational subroutine of the code is the WIGGLE¹ program, which contains both static and time-dependent solutions to the two-group diffusion

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

equation. The calculational flow for each assembly at start or end of subcycle consists of:

1. Input data processing,
2. A calculation of total and decay heat assembly powers versus time,
3. A static "search" calculation in which fission correction factors (multiplicative factors which modify the number of neutrons emitted per fission for each spatial point) are found which cause the calculated fission power shape to duplicate an input axial power shape, and
4. A time-dependent calculation in which thermal absorption is added from the top to simulate a safety rod scram.

Since AXLIB4 was designed to be implemented through LLAP and not as a stand-alone code, the input data are passed to the code from a driver routine and from JOSHUA interface records linking the code to the driver routine database. The required data for the code included:

- (1) Case name, error flag, decay heat model, and safety rod insertion model. These data are passed to the code from the driver routine.
- (2) The JOSHUA record *INPUT.AXLIB.INTERF1* which contains number of assembly types, number of flowzones, assembly names, assembly active lengths, coefficients for decay heat delta factors, flowzone exposures, and flowzone assembly types.
- (3) The JOSHUA record *INPUT.AXLIB.INTERF2* which contains number of spline intervals, abscissa values, and spline coefficients for fission power fit, tank level fit, moderated decay heat fit, and dry decay heat fit for all decay heat models.
- (4) The JOSHUA record *INPUT.LLAP.AXLIB.assemblyname.stage.casename* which contains time step increment, print flag, number of axial divisions in an assembly, number of axial shape points, number of initial axial power input space points, assembly cross sections, neutron velocities, safety rod

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

cross sections, precursor decay constants and yield fractions, and an initial power shape.

- (5) The JOSHUA record *INPUT.LLAP.AXLIB.ENDS.assemblyname.stage.casename* which contains the number of axial divisions in top and bottom endfittings, total height of top and bottom endfittings, total height of active center region, and neutron cross sections of top and bottom endfittings.

With the input data above, the code performs calculations and writes out the axial power shapes to the JOSHUA output records *OUTPUT.AXLIB2.TO.LLAP.assemblyname.time.stage.casename*. There is one JOSHUA output record for one assembly, at start or end of subcycle, and at a desired time.

II. VERIFICATION

As part of the certification process, AXLIB4 has to go through verification, a process to ensure that the coding correctly implements the intended calculational methods⁵. Since AXLIB4 is a small computer code using neutron diffusion theory, a well known theory which can be found in many nuclear engineering books, the verification process was performed by comparing the code line by line with the theory document¹ and with memos from the author during the coding. All discrepancies were corrected and reported in Software Discrepancy Report and Change Notices (SDCNs). AXLIB4 now is able to process the information as required.

III. VALIDATION

Validation refers to the process in which the accuracy of the whole code is determined. This process can be performed by comparing the code results with the experimental data, controlled experiments, operational data, or more accurate calculational methods (benchmarks⁵). For AXLIB4, the validation process was performed by the comparison of AXLIB4 results with a more accurate calculational method. With the simple geometrical situation modeled by AXLIB4, we are able to benchmark the code against analytical solutions of test problems. Two test problems from Reference 3 were

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

reused here. The first problem tests the calculation of total and decay heat assembly powers versus time and the calculation of the initial power profile. The test was performed by comparing AXLIB4 solutions of total and decay heat assembly powers versus time to the ones calculated by hand, and comparing AXLIB4 solutions of initial neutron flux profile and correction factors of a two-neutron-group reactor assembly with endfittings to the analytic one-group solution of the problem. The second problem tests the static and transient power shape calculations of the code. In this problem, the whole safety rod is inserted instantaneously; the spatial power shape of this problem is time-independent, but the power amplitude is time-dependent. The static calculation test was performed by comparing AXLIB4 solutions of neutron flux shapes and correction factors of a homogeneous reactor assembly (without endfittings) to the analytic two-group solutions of the same problem. The transient calculation test was performed by comparing the time behavior of AXLIB4 solutions to the analytical solutions.

IV. BENCHMARK PROBLEMS

IV.1. HETEROGENEOUS STATIC BENCHMARK PROBLEM

This first benchmark problem has a center region and two identical endfittings at top and bottom of the assembly. The code solves the problem with two energy groups and the analytical solution is performed by an identical one-energy-group problem. The problem configuration and data for both solutions are shown in the Appendix A.

IV.1.1. TOTAL AND DECAY HEAT POWER VERSUS TIME

From Reference 4, the formulation of total assembly deposited power is:

$$\begin{aligned} \Pi(t) = \Pi(0) \left\{ [1 - \delta_{\text{mod}} F_c^d(t)] \left[\frac{H(t)}{H(0)} \right] F^n(t) + \delta_{\text{mod}} F_c^d(t) \left[\frac{H(t)}{H(0)} \right] F_{\text{mod}}^d(t) \right. \\ \left. + \delta_{\text{dry}} F_c^d(t) \left[1 - \frac{H(t)}{H(0)} \right] F_{\text{dry}}^d(t) \right\} \end{aligned} \quad (1)$$

where:

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

- Π Total assembly deposited power,
- δ Fraction of deposited power from decay heat ("dry" for region where tank is empty, "mod" where assembly is moderated),
- H Height of water in the reactor tank,
- F^d Decay heat power amplitude ("dry" and "mode"), normalized to 1.0 at time 0.0,
- F^n Fission power plus neutron capture power amplitude, normalized to 1.0 at time 0.0,
- F_c^d Dry decay heat conservative factor, equal 1 for best estimate decay heat model.

The fission power amplitude calculated from AA3⁴ and the decay heat assembly power amplitude calculated from HMTABLE⁴ are functions of time, the height of water in the reactor tank is also a function of time, and the fraction of deposited power from decay heat is a function of exposure. These terms are fitted into polynomials by subroutine INPOWL in LLAP², and the polynomial coefficients are stored in the JOSHUA records *INPUT.AXLIB.INTERF1* and *INPUT.AXLIB.INTERF2*. The formulations of fission power amplitudes, ratio of water levels, decay heat power amplitudes, and fractions of decay heat power of an assembly are:

$$F^n(t) = C_1^{F^n}(t_j) + C_2^{F^n}(t_j) \Delta t_j + C_3^{F^n}(t_j) \frac{(\Delta t_j)^2}{2} + C_4^{F^n}(t_j) \frac{(\Delta t_j)^3}{6} ;$$

$$\frac{H(t)}{H(0)} = C_1^H(t_j) + C_2^H(t_j) \Delta t_j + C_3^H(t_j) \frac{(\Delta t_j)^2}{2} + C_4^H(t_j) \frac{(\Delta t_j)^3}{6} ;$$

$$F_x^d(t) = \frac{\sum_{k=1}^K \left[C_1^{F_x^d,k}(t_j) + C_2^{F_x^d,k}(t_j) \Delta t_j + C_3^{F_x^d,k}(t_j) \frac{(\Delta t_j)^2}{2} + C_4^{F_x^d,k}(t_j) \frac{(\Delta t_j)^3}{6} \right]}{K} ;$$

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

$$\delta_x = C_1^{\delta_x} + C_2^{\delta_x} (EX) + C_3^{\delta_x} (EX)^2 \quad (2)$$

where:

C	Spline coefficient,
C(EX)	Spline coefficient at assembly exposure EX,
C(t _j)	Spline coefficient at time t _j ,
I-1	Degree of polynomial,
Δt _j	t - t _j with t is desired time,
K	Number of flowzones in assembly,
x	mod, dry, or c,
EX	Average assembly exposure.

So, with the spline coefficients, AXLIB4 calculates total and decay heat assembly powers at the desired times by using equations (1) and (2). During the test, the calculations of equations (1) and (2) were performed by hand and the results were used to compare to the outputs from AXLIB4.

IV.1.2. ANALYTICAL SOLUTION OF POWER SHAPE

Since the assembly geometry is symmetric, the analytical solution to this problem is found by dividing the assembly by a midplane and setting up the one-dimensional one-energy-group diffusion equation for the center and endfitting regions. For the center region, the governing equation is (with subscript c denoting center):

$$-D_c \frac{d^2 \phi_c(x)}{dx^2} + \Sigma_{ac} \phi_c(x) = \frac{1}{k_{eff}} \nu \Sigma_{fc} \phi_c(x) \quad (3)$$

where:

D	=	Diffusion coefficient,
φ	=	Neutron flux,

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

- Σ_a = Neutron absorption cross section,
 k_{eff} = Average effective multiplication factor,
 ν = Average number of neutrons emitted per fission event,
 Σ_f = Neutron fission cross section.

The general solution for this equation is:

$$\phi_c(x) = A_1 \cos(Bx) + A_2 \sin(Bx) \quad (4)$$

where:

- A_1, A_2 are flux amplitudes depending on the power,
 B^2 is buckling coefficient.

Since the assembly is symmetric about the midplane and the material is homogeneous, the flux solution in the center region is also symmetric, that is:

$$\left. \frac{d\phi_c}{dx} \right|_0 = -BA_1 \sin(0) + BA_2 \cos(0) = 0$$

This leads to $A_2 = 0$ and the solution of the neutron flux is:

$$\phi_c(x) = A_1 \cos(Bx) = \phi_0 \cos(Bx) \quad (5)$$

Putting the neutron flux solution (5) into equation (3) we have:

$$D_c B^2 + \Sigma_{ac} = \frac{1}{k_{eff}} \nu \Sigma_{fc}$$

and the solution of the material dependent buckling coefficient is:

$$B^2 = B_m^2 = \frac{\frac{\nu \Sigma_{fc}}{k_{eff}} - \Sigma_{ac}}{D_c} \quad (6)$$

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

For the endfitting regions, there is no fission material in the region, the one-dimensional one-energy-group neutron diffusion equation becomes (with subscript e denoting endfittings):

$$-D_e \frac{d^2 \phi_e(x)}{dx^2} + \Sigma_{ae} \phi_e(x) = 0 \quad (7)$$

and the general solution is:

$$\phi_e(x) = C_1 \exp\left(\frac{x}{L}\right) + C_2 \exp\left(-\frac{x}{L}\right) \quad (8)$$

where:

C_1, C_2 are flux amplitudes depending on the power, and

$$L^2 = \frac{D_e}{\Sigma_{ae}} \text{ is the diffusion area.} \quad (9)$$

At the outside edge of the endfittings, zero flux boundary condition is applied, that is:

$$\phi_e(x_e) = C_1 \exp\left(\frac{x_e}{L}\right) + C_2 \exp\left(-\frac{x_e}{L}\right) = 0$$

which results in:

$$C_2 = -C_1 \frac{\exp\left(\frac{x_e}{L}\right)}{\exp\left(-\frac{x_e}{L}\right)} = -C_1 \exp\left(\frac{2x_e}{L}\right)$$

and the solution of neutron flux in the endfittings region becomes:

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

$$\begin{aligned}\phi_e(x) &= C_1 \exp\left(\frac{x}{L}\right) - C_1 \exp\left(\frac{2x_e}{L}\right) \exp\left(-\frac{x}{L}\right) \\ &= C_1 \left[\exp\left(\frac{x}{L}\right) - \exp\left(\frac{2x_e - x}{L}\right) \right]\end{aligned}\quad (10)$$

By the continuity condition of the neutron flux at the interface of the center and endfitting regions we have:

$$\phi_c(x_c) = \phi_0 \cos(Bx_c) = \phi_e(x_c) = C_1 \left[\exp\left(\frac{x_c}{L}\right) - \exp\left(\frac{2x_e - x_c}{L}\right) \right] \quad (11)$$

which results in:

$$C_1 = \frac{\phi_0 \cos(Bx_c)}{\left[\exp\left(\frac{x_c}{L}\right) - \exp\left(\frac{2x_e - x_c}{L}\right) \right]}$$

and the final solutions of the neutron flux are:

$$\begin{aligned}\phi(x) &= \frac{\phi_0 \cos(Bx_c)}{\left[\exp\left(\frac{x_c}{L}\right) - \exp\left(\frac{2x_e - x_c}{L}\right) \right]} \left[\exp\left(\frac{x}{L}\right) - \exp\left(\frac{2x_e - x}{L}\right) \right] \quad x_c \leq x \leq x_e \\ \phi(x) &= \phi_0 \cos(Bx) \quad 0 \leq x \leq x_c\end{aligned}\quad (12)$$

The geometry dependent buckling coefficient is found by using the continuity condition of the neutron current at the interface of the center and endfitting regions, that is:

$$\frac{d\phi_c}{dx} \Big|_{x_c} = -B\phi_0 \sin(Bx_c) = \frac{d\phi_e}{dx} \Big|_{x_c} = \frac{C_1}{L} \left[\exp\left(\frac{x_c}{L}\right) + \exp\left(\frac{2x_e - x_c}{L}\right) \right] \quad (13)$$

Dividing equation (13) by equation (11) we have the solution for the geometry dependent buckling coefficient:

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

$$-B \tan(Bx_c) = \frac{\left[\exp\left(\frac{x_c}{L}\right) + \exp\left(\frac{2x_e - x_c}{L}\right) \right]}{L \left[\exp\left(\frac{x_c}{L}\right) - \exp\left(\frac{2x_e - x_c}{L}\right) \right]} \quad (14)$$

and the solution for effective multiplication factor is obtained from equation (6) where B is from equation (14):

$$k_{eff} = \frac{v \Sigma_{fc}}{D_c B^2 + \Sigma_{ac}} \quad (15)$$

In the benchmark calculation, the initial neutron flux in the center region is normalized to unit average fission rate, that is:

$$2 \int_0^{x_c} \frac{\Sigma_{fc}}{k_{eff}} \phi_c(x) dx = \frac{2 \phi_0 \Sigma_{fc}}{k_{eff}} \int_0^{x_c} \cos(Bx) dx = 1.0$$

$$\phi_0 = \frac{k_{eff}}{2 \Sigma_{fc} \int_0^{x_c} \cos(Bx) dx}$$

and the initial neutron flux profile in the center region becomes:

$$\phi_c(x) = \frac{k_{eff}}{2 \Sigma_{fc} \int_0^{x_c} \cos(Bx) dx} \cos(Bx) \quad 0 \leq x \leq x_c \quad (16)$$

The initial power profile of the center region is:

$$p_c(x) = \frac{C \Sigma_{fc}}{k_{eff}} \phi_c(x) = \frac{C \Sigma_{fc}}{k_{eff}} \phi_0 \cos(Bx) = P_0 \cos(Bx) \quad 0 \leq x \leq x_c$$

where C or P_0 is a normalized constant such that:

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

$$\frac{2 \int_0^{x_c} p_c(x) dx}{2 \int_0^{x_c} dx} = \frac{P_0 \int_0^{x_c} \cos(Bx) dx}{x_c} = 1.0 \Rightarrow P_0 = \frac{x_c}{\int_0^{x_c} \cos(Bx) dx}$$

and the initial given power profile for the center region becomes:

$$p_c(x) = \frac{x_c}{\int_0^{x_c} \cos(Bx) dx} \cos(Bx) \quad 0 \leq x \leq x_c \quad (17)$$

The JOSHUA FORTRAN listing of this benchmark problem driver is AXLBE1.JOS, the JSIN file is AXLBE1.JSIN, the user input JOSHUA data set is AXLINP.DATA, the output JOSHUA data set is AXLOUT.DATA, and the result output file is AXLBE1.OUT. The analytical solutions of this benchmark problem are obtained by the program AXLAN1.FOR and the output file is AXLAN1.OUT. All of these files have been submitted to SCMS for archival.

The results of the analytical solutions and the solutions from AXLIB4 are shown in the Appendix A. Since the analytical k_{eff} is 0.99810760 and the average k_{eff} produced by AXLIB4 is 0.99810716, the k_{eff} solution from AXLIB4 is effectively identical to the analytical solution. From Fig. A.1 (graph of actual fission correction factor profile) we can see that the largest deviation of fission correction factors from the predicted value happens at the endpoints and is very small. The fast neutron group profile produced by AXLIB4 is also compared to the analytical solution as shown in Fig. A.2. The differences are too slight to show up on the graph with the largest difference being only 0.0178%.

IV.2. HOMOGENEOUS TIME DEPENDENT BENCHMARK PROBLEM

The second benchmark problem is a homogeneous assembly problem (there is no endfitting). The geometry configuration and cross sections are in the Appendix B. The benchmark and analytical solutions are solved with two neutron energy groups and six groups

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

of delay neutron precursors. The time dependent solutions are solved for the case of instantaneous full insertion (over the whole assembly length) of the safety rods at the beginning of the transient. The instantaneous full insertion causes the spatial configuration to be homogeneous throughout the transient, which guarantees that the initial spatial shape is preserved while the reactor power decays. The governing system of equations for this problem is:

$$\begin{aligned} \frac{1}{V^1} \frac{\partial \phi^1(x,t)}{\partial t} &= D^1 \frac{d^2 \phi^1(x,t)}{dx^2} + \frac{(1-\beta)}{k_{eff}} [v \Sigma_f^1 \phi^1(x,t) + v \Sigma_f^2 \phi^2(x,t)] \\ &\quad - \Sigma_R^1 \phi^1(x,t) + \sum_{i=1}^6 \lambda^i C^i(x,t) \\ \frac{1}{V^2} \frac{\partial \phi^2(x,t)}{\partial t} &= D^2 \frac{d^2 \phi^2(x,t)}{dx^2} - \Sigma_R^2 \phi^2(x,t) + \Sigma_s^{1 \rightarrow 2} \phi^1(x,t) \\ \frac{\partial C^i(x,t)}{\partial t} &= \frac{\beta^i}{k_{eff}} [v \Sigma_f^1 \phi^1(x,t) + v \Sigma_f^2 \phi^2(x,t)] - \lambda^i C^i(x,t); \quad i = 1, \dots, 6 \quad (18) \end{aligned}$$

where superscripts denote the neutron group and delay precursor number, and

- V^g = neutron velocity in group g ,
- $\Sigma_s^{1 \rightarrow 2}$ = scattering cross sections from group 1 to group 2,
- Σ_R^g = removal cross sections in group g ,
- C^i = density of delay neutron precursor group i ,
- λ^i = decay constant of delay neutron precursor group i ,
- β^i = fraction for delay neutron precursor group i ,
- β = fraction of total delay neutron = $\sum_{i=1}^6 \beta^i$

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

IV.2.1. ANALYTICAL SOLUTION OF THE INITIAL POWER SHAPE

The analytical solution for the initial flux profile is the solution of the two-group static diffusion equations. From equations (18) with setting time derivatives equal to zero and substituting equations of precursor concentrations into the neutron flux equations we have:

$$\begin{aligned} -D^1 \frac{d^2 \phi^1(x)}{dx^2} + \Sigma_R^1 \phi^1(x) &= \frac{1}{k_{eff}} [\nu \Sigma_f^1 \phi^1(x) + \nu \Sigma_f^2 \phi^2(x)] \\ -D^2 \frac{d^2 \phi^2(x)}{dx^2} + \Sigma_R^2 \phi^2(x) &= \Sigma_s^{1 \rightarrow 2} \phi^1(x) \end{aligned} \quad (19)$$

with the general solutions of:

$$\begin{aligned} \phi^1(x) &= A_1^1 \sin(Bx) + A_2^1 \cos(Bx) \\ \phi^2(x) &= A_1^2 \sin(Bx) + A_2^2 \cos(Bx) \end{aligned}$$

By the zero flux boundary condition at $x = 0.0$, the solution for neutron fluxes becomes:

$$\begin{aligned} \phi^1(x) &= A_1^1 \sin(Bx) = \phi_0^1 \sin(Bx) \\ \phi^2(x) &= A_1^2 \sin(Bx) = \phi_0^2 \sin(Bx) \end{aligned} \quad (20)$$

Substitute the solutions (20) into equations (19) and divide the system of equations by $\sin(Bx)$, we have:

$$\begin{aligned} D^1 B^2 \phi_0^1 + \Sigma_R^1 \phi_0^1 &= \frac{1}{k_{eff}} \nu \Sigma_f^1 \phi_0^1 + \frac{1}{k_{eff}} \nu \Sigma_f^2 \phi_0^2 \\ D^2 B^2 \phi_0^2 + \Sigma_R^2 \phi_0^2 &= \Sigma_s^{1 \rightarrow 2} \phi_0^1 \end{aligned}$$

or

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

$$\begin{aligned} \left(D^1 B^2 + \Sigma_R^1 - \frac{1}{k_{eff}} v \Sigma_f^1 \right) \phi_0^1 - \left(\frac{1}{k_{eff}} v \Sigma_f^2 \right) \phi_0^2 &= 0.0 \\ (\Sigma_s^{1 \rightarrow 2}) \phi_0^1 - (D^2 B^2 + \Sigma_R^2) \phi_0^2 &= 0.0 \end{aligned} \quad (21)$$

Solve equation (21) for neutron group 2 amplitude and effective multiplication factor as a function of neutron group 1 amplitude we have:

$$\phi_0^2 = \left(\frac{\Sigma_s^{1 \rightarrow 2}}{D^2 B^2 + \Sigma_R^2} \right) \phi_0^1 \quad (22)$$

$$k_{eff} = \frac{v \Sigma_f^1 (D^2 B^2 + \Sigma_R^2) + v \Sigma_f^2 \Sigma_s^{1 \rightarrow 2}}{(D^1 B^2 + \Sigma_R^1) (D^2 B^2 + \Sigma_R^2)} \quad (23)$$

To solve for the buckling coefficient B, apply the zero flux boundary condition at the edge of the assembly ($x=x_L$, where x_L is length of the assembly) we have:

$$\phi^1(x_L) = \phi_0^1 \sin(B x_L) = 0.0 ; \quad \phi^2(x_L) = \phi_0^2 \sin(B x_L) = 0.0$$

This will be satisfied if B assumes any of the values B_n , where

$$B_n x_L = (n+1) \pi \quad \text{or} \quad B_n = \frac{(n+1) \pi}{x_L} ; \quad n = 0, 1, 2, \dots, \infty$$

The various constants B_n are known as eigenvalues and the corresponding functions $\cos(B_n x)$ are called eigenfunctions. According to nuclear reactor theory for a critical assembly, all the eigenfunctions except the first one ($n=0$) die out in time and the steady-state flux shape is assumed by the first eigenfunction called the fundamental mode, that is:

$$B = B_0 = \frac{\pi}{x_L} \quad (24)$$

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

In the benchmark calculation, the initial neutron fluxes are normalized to unit average total fission rate:

$$\frac{\Sigma_f^1}{k_{eff}} \int_0^{x_L} \phi^1(x) dx + \frac{\Sigma_f^2}{k_{eff}} \int_0^{x_L} \phi^2(x) dx = 1.0$$

or

$$\frac{\Sigma_f^1}{k_{eff}} \int_0^{x_L} dx \left(\frac{\int_0^{x_L} \phi^1(x) dx}{\int_0^{x_L} dx} \right) + \frac{\Sigma_f^2}{k_{eff}} \int_0^{x_L} dx \left(\frac{\int_0^{x_L} \phi^2(x) dx}{\int_0^{x_L} dx} \right) = 1.0$$

Since $\int_0^{x_L} dx = x_L$ and $\frac{\int_0^{x_L} \phi^g(x) dx}{\int_0^{x_L} dx} = \bar{\phi}^g = \frac{2 \phi_0^g}{\pi}$ we have:

$$\frac{\Sigma_f^1}{k_{eff}} x_L \frac{2 \phi_0^1}{\pi} + \frac{\Sigma_f^2}{k_{eff}} x_L \frac{2 \phi_0^2}{\pi} = 1.0 \quad (25)$$

Substitute (22) into (25) and solve for neutron group 1 amplitude, we have:

$$\phi_0^1 = \frac{k_{eff} \pi (D^2 B^2 + \Sigma_R^2)}{2 x_L [(D^2 B^2 + \Sigma_R^2) \Sigma_f^1 + \Sigma_f^2 \Sigma_s^{1 \rightarrow 2}]} \quad (26)$$

and the power profile input is:

$$\begin{aligned} p(x) &= C \left(\frac{\Sigma_f^1}{k_{eff}} \phi^1(x) + \frac{\Sigma_f^2}{k_{eff}} \phi^2(x) \right) \\ &= C \left(\frac{\Sigma_f^1}{k_{eff}} \phi_0^1 + \frac{\Sigma_f^2}{k_{eff}} \phi_0^2 \right) \sin(Bx) = P_0 \sin(Bx) \end{aligned} \quad (27)$$

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

where C or P₀ is a normalized constant such that:

$$\frac{\int_0^{x_L} p(x) dx}{\int_0^{x_L} dx} = \frac{P_0 \int_0^{x_L} \sin(Bx) dx}{x_L} = 1.0 \Rightarrow P_0 = \frac{x_L}{\int_0^{x_L} \sin(Bx) dx} \quad (28)$$

IV.2.2. TIME DEPENDENT SOLUTIONS

Before solving the time dependent neutron fluxes, the static (initial) precursor concentrations have to be solved. From the third equation of equations (18) with the time derivative set to zero, we have:

$$C^i(x) = \frac{\beta^i}{\lambda^i k_{eff}} [v \Sigma_f^1 \phi^1(x) + v \Sigma_f^2 \phi^2(x)] = C_0^i \sin(Bx) ; i = 1, 2, \dots, 6 \quad (29)$$

$$\text{where } C_0^i = \frac{\beta^i}{\lambda^i k_{eff}} [v \Sigma_f^1 \phi_0^1 + v \Sigma_f^2 \phi_0^2]$$

The solution of time dependent neutron fluxes and precursor concentrations can be obtained by solving the system of equations (18) above. Assuming that both the neutron fluxes and precursor concentrations are separable in space and time, also with the same order of time derivative in the neutron and precursor equations, we assume that precursor concentrations are proportional in space and time to the neutron fluxes:

$$\begin{aligned} \phi^g(x,t) &= \phi^g w(t) u(x) ; g = 1, 2 \\ C^i(x,t) &= C^i w(t) u(x) ; i = 1, 2, \dots, 6 \end{aligned} \quad (30)$$

where $u(x)$ is a space-function, $w(t)$ is a time-function, C^i is amplitude of group i precursor concentration, and ϕ^g is amplitude of neutron group g .

Substituting (30) into (18) and simplify the resulting equations, we have:

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

$$\frac{\dot{w}(t)}{w(t)} = V^1 D^1 \frac{\ddot{u}(x)}{u(x)} + \frac{(1-\beta)V^1}{k_{eff}} \left(v\Sigma_f^1 + v\Sigma_f^2 \frac{\phi^2}{\phi^1} \right) - V^1 \Sigma_R^1 + \frac{V^1}{\phi^1} \sum_{i=1}^6 \lambda^i C^i$$

$$\frac{\dot{w}(t)}{w(t)} = V^2 D^2 \frac{\ddot{u}(x)}{u(x)} + V^2 \Sigma_s^{1 \rightarrow 2} \frac{\phi^1}{\phi^2} - V^2 \Sigma_R^2$$

$$\frac{\dot{w}(t)}{w(t)} = \frac{\beta^i}{k_{eff} C^i} (v\Sigma_f^1 \phi^1 + v\Sigma_f^2 \phi^2) - \lambda^i \quad ; \quad i = 1, 2, \dots, 6 \quad (31)$$

Since a time-dependent left-hand is equal to a space-dependent right-hand-side, both sides must be equal to a constant. Let's set,

$$\frac{\dot{w}(t)}{w(t)} = \alpha \quad \Rightarrow \quad w(t) = e^{\alpha t} \quad (32)$$

by using the initial condition of $w(0) = 1.0$, and

$$\frac{\ddot{u}(x)}{u(x)} = -B^2 \quad \Rightarrow \quad u(x) = \sin(Bx) \quad (33)$$

$$\text{where: } B = B_n = \frac{(n+1)\pi}{x_L} \quad ; \quad n = 0, 1, 2, \dots, \infty$$

by using the boundary condition of $u(0) = u(x_L) = 0.0$.

In this benchmark problem, since the thermal absorption cross section is homogeneously increased at the beginning of the transient, the initial spatial shape is preserved while the reactor power decays with time. Therefore, we are only concerned with the fundamental mode ($n=0$) of the spatial function. Substituting (32) into the third equation of system of equations (31) and solving for C^i , we have:

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

$$C^i = \frac{\beta^i}{(\alpha + \lambda^i)} \frac{(v\Sigma_f^1 \phi^1 + v\Sigma_f^2 \phi^2)}{k_{eff}} ; \quad i = 1, 2, \dots, 6 \quad (34)$$

Substituting (32), (33), and (34) into the first two equations in (31), we have:

$$\begin{aligned} & \left[\frac{\alpha}{V^1} - \frac{v\Sigma_f^1}{k_{eff}} \left(1 - \beta + \sum_{i=1}^6 \frac{\lambda^i \beta^i}{\alpha + \lambda^i} \right) + \Sigma_R^1 + D^1 B^2 \right] \phi^1 \\ & - \frac{v\Sigma_f^2}{k_{eff}} \left(1 - \beta + \sum_{i=1}^6 \frac{\lambda^i \beta^i}{\alpha + \lambda^i} \right) \phi^2 = 0.0 \\ & \Sigma_s^{1 \rightarrow 2} \phi^1 + \left[\frac{\alpha}{V^2} + \Sigma_R^2 + D^2 B^2 \right] \phi^2 = 0.0 \end{aligned} \quad (35)$$

We can rearrange this to get:

$$\begin{aligned} B^2 = & - \frac{\alpha}{V^1 D^1} + \frac{(1-\beta)}{D^1 \phi^1} \frac{(v\Sigma_f^1 \phi^1 + v\Sigma_f^2 \phi^2)}{k_{eff}} - \frac{\Sigma_R^1}{D^1} \\ & + \frac{1}{D^1 \phi^1} \frac{(v\Sigma_f^1 \phi^1 + v\Sigma_f^2 \phi^2)}{k_{eff}} \sum_{i=1}^6 \lambda^i \frac{\beta^i \lambda^i}{(\alpha + \lambda^i)} \\ B^2 = & - \frac{\alpha}{V^2 D^2} + \frac{\Sigma_s^{1 \rightarrow 2} \phi^1}{D^2 \phi^2} - \frac{\Sigma_R^2}{D^2} \end{aligned} \quad (36)$$

Since the first equation (36) is an "inhour-type" equation with seven roots, we have a total of eight time-eigenvalues α_n , $n = 1, 2, \dots, 8$ for a fundamental spatial-eigenvalue B . Using the general expansion theorem, we can now write the time dependent solution of the neutron and precursors:

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

$$\phi^g(x,t) = \sum_{n=1}^8 a_n \phi_n^g \exp(\alpha_n t) \sin(Bx) = \phi_t^g(t) \sin(Bx) \quad ; \quad g = 1, 2$$

$$\text{with } \phi_t^g(t) = \sum_{n=1}^8 a_n \phi_n^g \exp(\alpha_n t)$$

$$C^i(x,t) = \sum_{n=1}^8 a_n C_n^i \exp(\alpha_n t) \sin(Bx) = C_t^i(t) \sin(Bx) \quad ; \quad i = 1, 2, \dots, 6$$

$$\text{with } C_t^i(t) = \sum_{n=1}^8 a_n C_n^i \exp(\alpha_n t) \quad (37)$$

where ϕ_n^g, C_n^i are eigenmode coefficients (ϕ^g, C^i) corresponding to time-eigenvalues α_n and a_n are factors normalize to initial conditions.

At time zero, comparing equations (37) to (20) and (29) gives us:

$$\phi^g(x,0) = \sum_{n=1}^8 a_n \phi_n^g \exp(0) \sin(Bx) = \sum_{n=1}^8 a_n \phi_n^g [\sin(Bx)] = \phi_0^g \sin(Bx)$$

$$\Rightarrow \sum_{n=1}^8 a_n \phi_n^1 = \phi_t^1(0) = \phi_0^1 \quad ; \quad \sum_{n=1}^8 a_n \phi_n^2 = \phi_t^2(0) = \phi_0^2$$

$$C^i(x,0) = \sum_{n=1}^8 a_n C_n^i \exp(0) \sin(Bx) = \sum_{n=1}^8 a_n C_n^i [\sin(Bx)] = C_0^i \sin(Bx)$$

$$\Rightarrow \sum_{n=1}^8 a_n C_n^i = C_t^i(0) = C_0^i \quad ; \quad i = 1, 2, \dots, 6 \quad (38)$$

or in the matrix form:

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

$$\begin{bmatrix} \phi_1^1 & \phi_2^1 & \dots & \phi_8^1 \\ \phi_1^2 & \phi_2^2 & & \phi_8^2 \\ C_1^1 & C_2^1 & & C_8^1 \\ C_1^2 & C_2^2 & & C_8^2 \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ C_1^6 & C_2^6 & & C_8^6 \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \\ a_6 \\ a_7 \\ a_8 \end{bmatrix} = \begin{bmatrix} \phi_0^1 \\ \phi_0^2 \\ C_0^1 \\ C_0^2 \\ \cdot \\ \cdot \\ \cdot \\ C_0^6 \end{bmatrix} ; \quad [\Phi] [a] = [\phi] \quad (39)$$

For each time-eigenvalue α_n , the corresponding arbitrary value of eigenmode coefficients ϕ_n^g, C_n^i are calculated by equations (35) and (34). When all of the eight eigenvectors are calculated, the normalized factors a_n are then calculated by solving the system of equations (39) and the time-dependent amplitudes of the neutron fluxes $\phi_t^g(t)$ and precursors $C_t^i(t)$ are calculated from equations (37).

The JOSHUA FORTRAN listing of this benchmark problem driver is AXLBE2.JOS, the JSIN file is AXLBE2.JSIN, the user input JOSHUA data set is AXLINP.DATA, the output JOSHUA data set is AXLOU DATA, and the output file is AXLBE2.OUT. The analytical solution of this benchmark problem are obtained by the program AXLAN2 PR, and the output are AXLAN2.OUT. All of files above have been submitted to SCMS for archival.

The results of the analytical solutions and the solutions from AXLIB4 of this benchmark problem are shown in the Appendix B. Since the analytical k_{eff} is 0.99860700 and the average k_{eff} produced by AXLIB4 is 0.99860434, the k_{eff} solution from AXLIB4 is effectively identical to the analytical solution. The initial neutron flux distributions and the time dependent reactor power decay produced by AXLIB4 are also compared to the analytical solutions as shown in Fig. B.1 and Fig. B.2. The differences are too slight to show up on the graphs.

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

V. CONCLUSIONS

AXLIB4 has been tested by comparing the results of test problems to the hand calculations and to the analytical diffusion theory solutions which test the space- and time-dependent calculational abilities. In all cases, AXLIB4 solutions were essentially identical to the analytical solutions as shown in the Appendices.

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

APPENDIX A

DATA & RESULTS FOR PROBLEM 1

A.1 GEOMETRY

	TOP REGION	CENTER REGION	BOTTOM REGION
Length (inch)	20.0	150.0	20.0
Number of mesh	20	150	20
Mesh size (inch)	1.0	1.0	1.0

A.2 PHYSICS DATA

DATA FROM INPUT.AXLIB.INTERF1

NUMBER OF ASSEMBLY TYPES = : 1
NUMBER OF FLOW ZONES = : 1

ASSEMBLY NAME :mk22
ASS. ACTIVE LENGTH (FT) :12.5000E+00

COEFFICIENTS FOR DECAY HEAT DELTA FACTOR MODERATED TANK

C1 = :53.6016E-03 C2 = :17.3327E-06 C3 = :-1.2524E-07

DRY TANK

C1 = :66.3764E-03 C2 = :12.0575E-06 C3 = :-4.7585E-08

START OF SUBCYCLE EXPOSURE BY FLOWZONE = :00.0000E+00
ASSEMBLY TYPE NUMBER BY FLOWZONE . 1

DATA FROM INPUT.AXLIB.INTERF2

NO. OF SPLINE INTERVALS, FISS. POWER AT START OF SUBCYC. = : 20
NUMBER OF SPLINE INTERVALS, TANK LEVEL = : 4
NUMBER OF SPLINE INTERVALS, MODERATED DECAY HEAT = : 30
NUMBER OF SPLINE INTERVALS, DRY DECAY HEAT (BEST ESTIMATE) = : 30
NUMBER OF SPLINE INTERVALS, DRY DECAY HEAT (CONSERVATIVE) = : 30
NUMBER OF FLOW ZONES = : 1

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

ABSCISSA AND SPLINE COEFF. FOR FISS. POWER AT START OF SUBCYCLE

	T	C1	C2	C3	C4
1	:00.0000E+00	:10.0000E-01	:46.8063E-03	:-7.2280E-19	:-4.8930E-02
2	:24.0000E-01	:99.9600E-02	:-9.4113E-02	:-1.1743E-01	:59.0642E-02
3	:25.0000E-01	:98.9700E-02	:-1.0290E-01	:-5.8368E-02	:-1.1508E+01
4	:26.0000E-01	:97.7200E-02	:-1.6628E-01	:-1.2091E+00	:17.2416E+00
5	:27.0000E-01	:95.7400E-02	:-2.0098E-01	:51.5019E-02	:-5.2060E+01
6	:28.0000E-01	:93.1200E-02	:-4.0978E-01	:-4.6910E+00	:28.4004E+00
7	:29.0000E-01	:87.1500E-02	:-7.3688E-01	:-1.8510E+00	:10.4657E+01
8	:30.0000E-01	:80.6000E-02	:-3.9869E-01	:86.1474E-01	:-1.5183E+02
9	:31.0000E-01	:78.3900E-02	:-2.9635E-01	:-6.5679E+00	:11.2649E+01
10	:32.0000E-01	:74.0200E-02	:-3.8990E-01	:46.9700E-01	:-2.6337E+02
11	:33.0000E-01	:68.0800E-02	:-1.2371E+00	:-2.1640E+01	:50.5836E+01
12	:34.0000E-01	:53.3200E-02	:-8.7188E-01	:28.9435E+00	:-3.4518E+02
13	:35.0000E-01	:53.3200E-02	:29.6586E-02	:-5.5742E+00	:23.9916E+00
14	:38.0000E-01	:47.9300E-02	:-2.9605E-01	:16.2331E-01	:-4.0508E+00
15	:43.0000E-01	:44.9800E-02	:92.6329E-04	:-4.0207E-01	:98.5329E-02
16	:48.0000E-01	:42.4700E-02	:-6.8608E-02	:90.5897E-03	:-1.0372E-01
17	:58.0000E-01	:38.4100E-02	:-2.9879E-02	:-1.3131E-02	:23.6669E-03
18	:68.0000E-01	:35.1600E-02	:-3.1177E-02	:10.5356E-03	:-7.7467E-03
19	:78.0000E-01	:32.4400E-02	:-2.4514E-02	:27.8895E-04	:18.8162E-05
20	:98.0000E-01	:28.1200E-02	:-1.8560E-02	:31.6527E-04	:-1.5826E-03

ABSCISSA AND SPLINE COEFF. FOR TANK LEVEL

	T	C1	C2	C3	C4
1	:00.0000E+00	:10.0000E-01	:00.0000E+00	:00.0000E+00	:00.0000E+00
2	:20.0000E+01	:10.0000E-01	:00.0000E+00	:00.0000E+00	:00.0000E+00
3	:40.0000E+01	:10.0000E-01	:00.0000E+00	:00.0000E+00	:00.0000E+00
4	:60.0000E+01	:10.0000E-01	:00.0000E+00	:00.0000E+00	:00.0000E+00

ABSCISSA AND SPLINE COEFF. FOR MODERATED DECAY HEAT AT START OF SUBCYCLE

	T	C1	C2	C3	C4
1	:00.0000E+00	:10.0000E-01	:-1.2189E-12	:00.0000E+00	:73.1326E-03
2	:10.0000E-06	:10.0000E-01	:24.3775E-13	:73.1326E-08	:-3.6566E-01
3	:20.0000E-06	:10.0000E-01	:-8.5321E-12	:-2.9253E-06	:13.8952E-01
4	:30.0000E-06	:10.0000E-01	:31.6908E-12	:10.9699E-06	:-5.1924E+00
5	:40.0000E-06	:10.0000E-01	:-1.1823E-10	:-4.0954E-05	:19.3802E+00
6	:50.0000E-06	:10.0000E-01	:44.1233E-11	:15.2847E-05	:-7.2328E+01
7	:60.0000E-06	:10.0000E-01	:-1.6467E-09	:-5.7043E-04	:26.9933E+01
8	:70.0000E-06	:10.0000E-01	:61.4558E-10	:21.2889E-04	:-1.0074E+03
9	:80.0000E-06	:10.0000E-01	:-2.2936E-08	:-7.9451E-03	:37.5967E+02
10	:90.0000E-06	:10.0000E-01	:85.5969E-09	:29.6516E-03	:-1.4031E+04
11	:10.0000E-05	:10.0000E-01	:-3.1945E-07	:-1.1066E-01	:77.4132E-03
12	:24.0010E-01	:85.9654E-02	:-4.2638E-02	:75.1303E-03	:-8.3201E-01
13	:25.0010E-01	:85.5628E-02	:-3.9285E-02	:-8.0703E-03	:21.7623E-02
14	:26.0010E-01	:85.1695E-02	:-3.9004E-02	:13.6920E-03	:-6.1676E-02
15	:27.0010E-01	:84.7853E-02	:-3.7943E-02	:75.2434E-04	:11.8063E-03
16	:28.0010E-01	:84.4098E-02	:-3.7131E-02	:87.0497E-04	:-6.8991E-03
17	:29.0010E-01	:84.0428E-02	:-3.6295E-02	:80.1506E-04	:-2.1962E-03
18	:30.0010E-01	:83.6838E-02	:-3.5505E-02	:77.9544E-04	:-2.8597E-03
19	:31.0010E-01	:83.3326E-02	:-3.4739E-02	:75.0947E-04	:-2.7673E-03
20	:32.0010E-01	:82.9889E-02	:-3.4002E-02	:72.3274E-04	:-2.2625E-03
21	:33.0010E-01	:82.6524E-02	:-3.3290E-02	:70.0648E-04	:-3.1066E-03
22	:34.0010E-01	:82.3230E-02	:-3.2605E-02	:66.9582E-04	:-1.8563E-03

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

23	:35.0010E-01	:82.0003E-02	:-3.1945E-02	:65.1020E-04	:-2.2493E-03
24	:38.0010E-01	:81.0702E-02	:-3.0093E-02	:58.3540E-04	:-1.8085E-03
25	:43.0010E-01	:79.6347E-02	:-2.7401E-02	:49.3115E-04	:-1.4794E-03
26	:48.0010E-01	:78.3232E-02	:-2.5121E-02	:41.9143E-04	:-1.1085E-03
27	:58.0010E-01	:76.0022E-02	:-2.1484E-02	:30.8292E-04	:-6.1027E-04
28	:68.0010E-01	:73.9978E-02	:-1.8706E-02	:24.7265E-04	:-8.7671E-04
29	:78.0010E-01	:72.2363E-02	:-1.6672E-02	:15.9594E-04	:22.6711E-05
30	:98.0010E-01	:69.2514E-02	:-1.3026E-02	:20.4936E-04	:-1.0247E-03

ABSCISSA AND SPLINE COEFF. FOR DRY DECAY HEAT (B.E.) AT START OF SUBCYCLE

	T	C1	C2	C3	C4
1	:00.0000E+00	:10.0000E-01	:-1.1938E-12	:00.0000E+00	:71.6263E-03
2	:10.0000E-06	:10.0000E-01	:23.8754E-13	:71.6263E-08	:-3.5813E-01
3	:20.0000E-06	:10.0000E-01	:-8.3564E-12	:-2.8651E-06	:13.6090E-01
4	:30.0000E-06	:10.0000E-01	:31.0381E-12	:10.7439E-06	:-5.0855E+00
5	:40.0000E-06	:10.0000E-01	:-1.1580E-10	:-4.0111E-05	:18.9810E+00
6	:50.0000E-06	:10.0000E-01	:43.2145E-11	:14.9699E-05	:-7.0838E+01
7	:60.0000E-06	:10.0000E-01	:-1.6128E-09	:-5.5868E-04	:26.4373E+01
8	:70.0000E-06	:10.0000E-01	:60.1899E-10	:20.8504E-04	:-9.8665E+02
9	:80.0000E-06	:10.0000E-01	:-2.2463E-08	:-7.7815E-03	:36.8223E+02
10	:90.0000E-06	:10.0000E-01	:83.8338E-09	:29.0409E-03	:-1.3742E+04
11	:10.0000E-05	:10.0000E-01	:-3.1287E-07	:-1.0838E-01	:75.9312E-03
12	:24.0010E-01	:86.2805E-02	:-4.1435E-02	:73.8530E-03	:-8.1667E-01
13	:25.0010E-01	:85.8894E-02	:-3.8133E-02	:-7.8135E-03	:21.3265E-02
14	:26.0010E-01	:85.5077E-02	:-3.7848E-02	:13.5130E-03	:-6.0304E-02
15	:27.0010E-01	:85.1350E-02	:-3.6798E-02	:74.8260E-04	:11.0358E-03
16	:28.0010E-01	:84.7709E-02	:-3.5995E-02	:85.8617E-04	:-5.9078E-03
17	:29.0010E-01	:84.4152E-02	:-3.5166E-02	:79.9539E-04	:-2.8844E-03
18	:30.0010E-01	:84.0675E-02	:-3.4381E-02	:77.0695E-04	:-2.8879E-03
19	:31.0010E-01	:83.7275E-02	:-3.3625E-02	:74.1816E-04	:-1.9679E-03
20	:32.0010E-01	:83.3949E-02	:-3.2893E-02	:72.2138E-04	:-3.2833E-03
21	:33.0010E-01	:83.0695E-02	:-3.2187E-02	:68.9304E-04	:-2.3294E-03
22	:34.0010E-01	:82.7511E-02	:-3.1509E-02	:66.6010E-04	:-2.1529E-03
23	:35.0010E-01	:82.4393E-02	:-3.0854E-02	:64.4481E-04	:-2.2053E-03
24	:38.0010E-01	:81.5417E-02	:-2.9020E-02	:57.8323E-04	:-1.7982E-03
25	:43.0010E-01	:80.1592E-02	:-2.6353E-02	:48.8411E-04	:-1.4797E-03
26	:48.0010E-01	:78.8995E-02	:-2.4096E-02	:41.4425E-04	:-1.0822E-03
27	:58.0010E-01	:76.6791E-02	:-2.0493E-02	:30.6202E-04	:-6.6778E-04
28	:68.0010E-01	:74.7718E-02	:-1.7765E-02	:23.9423E-04	:-6.3968E-04
29	:78.0010E-01	:73.1044E-02	:-1.5690E-02	:17.5455E-04	:-1.2504E-04
30	:98.0010E-01	:70.3006E-02	:-1.2431E-02	:15.0447E-04	:-7.5223E-04

ABSCISSA AND SPLINE COEFF. FOR DRY DECAY HEAT (CON.) AT START OF SUBCYCLE

	T	C1	C2	C3	C4
1	:00.0000E+00	:10.7742E-01	:-2.7392E-13	:00.0000E+00	:16.4354E-03
2	:10.0000E-06	:10.7742E-01	:54.7846E-14	:16.4354E-08	:-8.2177E-02
3	:20.0000E-06	:10.7742E-01	:-1.9175E-12	:-6.5742E-07	:31.2272E-02
4	:30.0000E-06	:10.7742E-01	:71.2200E-13	:24.6531E-07	:-1.1669E+00
5	:40.0000E-06	:10.7742E-01	:-2.6571E-11	:-9.2038E-06	:43.5538E-01
6	:50.0000E-06	:10.7742E-01	:99.1601E-12	:34.3499E-06	:-1.6255E+01
7	:60.0000E-06	:10.7742E-01	:-3.7007E-10	:-1.2820E-04	:60.6630E+00
8	:70.0000E-06	:10.7742E-01	:13.8112E-10	:47.8434E-05	:-2.2640E+02
9	:80.0000E-06	:10.7742E-01	:-5.1544E-09	:-1.7855E-03	:84.4926E+01
10	:90.0000E-06	:10.7742E-01	:19.2365E-09	:66.6372E-04	:-3.1533E+03
11	:10.0000E-05	:10.7742E-01	:-7.1792E-08	:-2.4869E-02	:19.6784E-03

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

12	:24.0010E-01	:10.5114E-01	:-3.0126E-03	:22.3589E-03	:-2.9226E-01
13	:25.0010E-01	:10.5090E-01	:-2.2381E-03	:-6.8672E-03	:79.0007E-03
14	:26.0010E-01	:10.5066E-01	:-2.5298E-03	:10.3288E-04	:-2.1592E-02
15	:27.0010E-01	:10.5040E-01	:-2.5345E-03	:-1.1264E-03	:66.4659E-04
16	:28.0010E-01	:10.5015E-01	:-2.6139E-03	:-4.6170E-04	:-2.1255E-03
17	:29.0010E-01	:10.4988E-01	:-2.6707E-03	:-6.7426E-04	:11.3273E-04
18	:30.0010E-01	:10.4961E-01	:-2.7324E-03	:-5.6098E-04	:-2.5588E-04
19	:31.0010E-01	:10.4934E-01	:-2.7898E-03	:-5.8657E-04	:61.0121E-05
20	:32.0010E-01	:10.4905E-01	:-2.8454E-03	:-5.2556E-04	:-1.4774E-03
21	:33.0010E-01	:10.4877E-01	:-2.9053E-03	:-6.7330E-04	:74.5350E-04
22	:34.0010E-01	:10.4847E-01	:-2.9354E-03	:72.0506E-06	:-2.9060E-02
23	:35.0010E-01	:10.4818E-01	:-3.0735E-03	:-2.8340E-03	:27.9084E-03
24	:38.0010E-01	:10.4725E-01	:-2.6678E-03	:55.3853E-04	:-7.6271E-03
25	:43.0010E-01	:10.4645E-01	:-8.5194E-04	:17.2498E-04	:-5.3529E-03
26	:48.0010E-01	:10.4613E-01	:-6.5856E-04	:-9.5147E-04	:18.7910E-04
27	:58.0010E-01	:10.4531E-01	:-6.7048E-04	:92.7631E-05	:-1.0975E-03
28	:68.0010E-01	:10.4492E-01	:-2.9158E-04	:-1.6982E-04	:50.2372E-06
29	:78.0010E-01	:10.4455E-01	:-4.3628E-04	:-1.1959E-04	:18.2924E-05
30	:98.0010E-01	:10.4368E-01	:-3.0961E-04	:24.6262E-05	:-1.2313E-04

TWO-GROUP CROSS SECTIONS

	CORE		ENDFITTINGS	
	GRP1	GRP2	GRP1	GRP2
Diffusion (cm)	1.000000	0.931790	1.000000	0.945940
Removal (/cm)	0.024000	0.011410	0.000200	0.002602
Capture (/cm)	0.010000	0.011410	0.000100	0.002602
Fission (/cm)	0.010000	0.000000	0.000000	0.000000
Nu*fission (/cm)	0.024000	0.000000	0.000000	0.000000
Scatt. 1-> (/cm)	0.000000	0.004000	0.000000	0.000100
Scatt. 2-> (/cm)	0.000000	0.000000	0.000000	0.000000

IDENTICAL ONE-GROUP CROSS SECTIONS FOR ANALYTICAL SOLUTIONS

	CORE	ENDFITTINGS
Diffusion (cm)	1.000000	1.000000
Removal (/cm)	0.024000	0.000200
Capture (/cm)	0.014000	0.000200
Fission (/cm)	0.010000	0.000000
Nu*fission (/cm)	0.024000	0.000000

Verification, Validation, and Benchmarking Report for AXLIB4 (U)**A.3 RESULTS****DECAY HEAT POWER CALCULATIONS AT START OF SUBCYCLE**

TIME	AXLIB4	HAND-CALCULATION
0.0000	0.0578	0.0578
0.9000	0.0553	0.0553
1.0000	0.0548	0.0548
1.1000	0.0543	0.0543
1.2000	0.0538	0.0538
1.3000	0.0533	0.0533
1.4000	0.0528	0.0528
1.5000	0.0522	0.0522
1.6000	0.0517	0.0517
1.7000	0.0512	0.0512
1.8000	0.0507	0.0507
1.9000	0.0503	0.0503
2.0000	0.0498	0.0498
2.3000	0.0487	0.0487
2.8000	0.0475	0.0475
3.3000	0.0465	0.0465
4.3000	0.0447	0.0447
5.3000	0.0432	0.0432
6.3000	0.0420	0.0420
8.3000	0.0400	0.0400
10.3000	0.0384	0.0384

TOTAL AVERAGE POWER CALCULATIONS AT START OF SUBCYCLE

TIME	AXLIB4	HAND-CALCULATION
0.0000	1.0000	1.0000
0.9000	1.0321	1.0321
1.0000	1.0340	1.0340
1.1000	1.0355	1.0355
1.2000	1.0364	1.0364
1.3000	1.0368	1.0368
1.4000	1.0365	1.0365
1.5000	1.0357	1.0357
1.6000	1.0341	1.0341
1.7000	1.0318	1.0318
1.8000	1.0287	1.0287
1.9000	1.0248	1.0248
2.0000	1.0201	1.0201
2.3000	1.0003	1.0003
2.8000	0.9263	0.9263
3.3000	0.6890	0.6890
4.3000	0.4692	0.4692
5.3000	0.4204	0.4204
6.3000	0.3894	0.3894

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

8.3000	0.3350	0.3350
10.3000	0.2954	0.2954

FISSION CORRECTION FACTORS

	AXLIB4	ANALYTICAL	%DIFFERENT
Ave. Eff. Multi. Factor	0.99810716	0.99810760	4.4083E-5
Ave. Fiss. Corec. Factor	1.00189642	1.00189599	4.2918E-5

FISSION CORRECTION FACTORS OF CENTER
REGION VS. AXIAL POSITIONS (AXLIB4)

X(IN.)	F.C.	X(IN)	F.C.	X(IN.)	F.C.
20.5	1.00188100	21.5	1.00188637	22.5	1.00188947
23.5	1.00189185	24.5	1.00189352	25.5	1.00189412
26.5	1.00189495	27.5	1.00189531	28.5	1.00189519
29.5	1.00189555	30.5	1.00189555	31.5	1.00189567
32.5	1.00189579	33.5	1.00189579	34.5	1.00189579
35.5	1.00189590	36.5	1.00189579	37.5	1.00189590
38.5	1.00189579	39.5	1.00189590	40.5	1.00189590
41.5	1.00189590	42.5	1.00189567	43.5	1.00189567
44.5	1.00189579	45.5	1.00189579	46.5	1.00189579
47.5	1.00189590	48.5	1.00189579	49.5	1.00189590
50.5	1.00189579	51.5	1.00189579	52.5	1.00189579
53.5	1.00189567	54.5	1.00189579	55.5	1.00189567
56.5	1.00189555	57.5	1.00189555	58.5	1.00189567
59.5	1.00189567	60.5	1.00189567	61.5	1.00189567
62.5	1.00189555	63.5	1.00189567	64.5	1.00189555
65.5	1.00189555	66.5	1.00189567	67.5	1.00189579
68.5	1.00189579	69.5	1.00189567	70.5	1.00189579
71.5	1.00189590	72.5	1.00189567	73.5	1.00189579
74.5	1.00189579	75.5	1.00189567	76.5	1.00189579
77.5	1.00189567	78.5	1.00189567	79.5	1.00189555
80.5	1.00189567	81.5	1.00189567	82.5	1.00189567
83.5	1.00189567	84.5	1.00189567	85.5	1.00189579
86.5	1.00189567	87.5	1.00189567	88.5	1.00189555
89.5	1.00189555	90.5	1.00189567	91.5	1.00189567
92.5	1.00189555	93.5	1.00189555	94.5	1.00189555
95.5	1.00189555	96.5	1.00189567	97.5	1.00189567
98.5	1.00189567	99.5	1.00189579	100.5	1.00189555
101.5	1.00189555	102.5	1.00189567	103.5	1.00189567
104.5	1.00189555	105.5	1.00189555	106.5	1.00189579
107.5	1.00189579	108.5	1.00189567	109.5	1.00189567
110.5	1.00189555	111.5	1.00189555	112.5	1.00189555
113.5	1.00189579	114.5	1.00189555	115.5	1.00189567
116.5	1.00189579	117.5	1.00189555	118.5	1.00189590
119.5	1.00189567	120.5	1.00189567	121.5	1.00189567
122.5	1.00189567	123.5	1.00189567	124.5	1.00189567
125.5	1.00189567	126.5	1.00189567	127.5	1.00189555
128.5	1.00189567	129.5	1.00189567	130.5	1.00189567
131.5	1.00189567	132.5	1.00189567	133.5	1.00189567
134.5	1.00189579	135.5	1.00189579	136.5	1.00189567
137.5	1.00189567	138.5	1.00189555	139.5	1.00189567

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

140.5	1.00189590	141.5	1.00189567	142.5	1.00189579
143.5	1.00189579	144.5	1.00189579	145.5	1.00189567
146.5	1.00189567	147.5	1.00189567	148.5	1.00189567
149.5	1.00189567	150.5	1.00189579	151.5	1.00189567
152.5	1.00189579	153.5	1.00189555	154.5	1.00189567
155.5	1.00189555	156.5	1.00189567	157.5	1.00189567
158.5	1.00189567	159.5	1.00189543	160.5	1.00189531
161.5	1.00189507	162.5	1.00189495	163.5	1.00189471
164.5	1.00189400	165.5	1.00189304	166.5	1.00189161
167.5	1.00188911	168.5	1.00188613	169.5	1.00188065

Fig. A.1: Fission Correction Factors vs. Axial Positions

COMPARISON OF FLUX PROFILES

x(in.)	ANALYTICAL		AXLIB4	
	GROUP1	GROUP1	GROUP2	
0.5	5.77119728E-03	5.77020971E-03	8.24220537E-04	
1.5	1.73210393E-02	1.73180755E-02	2.48335302E-03	
2.5	2.88932335E-02	2.88882852E-02	4.17474518E-03

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

3.5	4.05027131E-02	4.04957719E-02	5.92052191E-03
4.5	5.21644598E-02	5.21555170E-02	7.74374744E-03
5.5	6.38935227E-02	6.38825595E-02	9.66882706E-03
6.5	7.57050374E-02	7.56920278E-02	1.17219239E-02
7.5	8.76142465E-02	8.75991657E-02	1.39314216E-02
8.5	9.96365180E-02	9.96193439E-02	1.63284093E-02
9.5	1.11787366E-01	1.11768059E-01	1.89472269E-02
10.5	1.24082472E-01	1.24060996E-01	2.18260605E-02
11.5	1.36537700E-01	1.36514008E-01	2.50076186E-02
12.5	1.49169125E-01	1.49143174E-01	2.85398681E-02
13.5	1.61993047E-01	1.61964774E-01	3.24768797E-02
14.5	1.75026014E-01	1.74995393E-01	3.68797779E-02
15.5	1.88284845E-01	1.88251793E-01	4.18178067E-02
16.5	2.01786649E-01	2.01751098E-01	4.73695695E-02
17.5	2.15548851E-01	2.15510741E-01	5.36243729E-02
18.5	2.29589210E-01	2.29548439E-01	6.06838353E-02
19.5	2.43925844E-01	2.43882343E-01	6.86636791E-02
20.5	2.58527034E-01	2.58530945E-01	7.77643025E-02
21.5	2.73101583E-01	2.73104250E-01	8.59168470E-02
22.5	2.87595960E-01	2.87597775E-01	9.32931900E-02
23.5	3.02005908E-01	3.02007139E-01	1.00074664E-01
24.5	3.16327199E-01	3.16328019E-01	1.06397949E-01
25.5	3.30555627E-01	3.30556214E-01	1.12365954E-01
26.5	3.44687015E-01	3.44687402E-01	1.18056118E-01
27.5	3.58717216E-01	3.58717501E-01	1.23526588E-01
28.5	3.72642110E-01	3.72642338E-01	1.28820971E-01
29.5	3.86457610E-01	3.86457771E-01	1.33971900E-01
30.5	4.00159659E-01	4.00159806E-01	1.39003664E-01
31.5	4.13744236E-01	4.13744390E-01	1.43934295E-01
32.5	4.27207353E-01	4.27207470E-01	1.48777068E-01
33.5	4.40545056E-01	4.40545112E-01	1.53541714E-01
34.5	4.53753431E-01	4.53753442E-01	1.58235237E-01
35.5	4.66828600E-01	4.66828614E-01	1.62862659E-01
36.5	4.79766725E-01	4.79766756E-01	1.67427376E-01
37.5	4.92564007E-01	4.92564082E-01	1.71931714E-01
38.5	5.05216691E-01	5.05216777E-01	1.76377103E-01
39.5	5.17721060E-01	5.17721117E-01	1.80764303E-01
40.5	5.30073445E-01	5.30073524E-01	1.85093582E-01
41.5	5.42270220E-01	5.42270303E-01	1.89364851E-01
42.5	5.54307803E-01	5.54307938E-01	1.93577766E-01
43.5	5.66182661E-01	5.66182852E-01	1.97731763E-01
44.5	5.77891308E-01	5.77891469E-01	2.01826140E-01
45.5	5.89430307E-01	5.89430451E-01	2.05860078E-01
46.5	6.00796269E-01	6.00796402E-01	2.09832683E-01
47.5	6.11985860E-01	6.11985981E-01	2.13743016E-01
48.5	6.22995793E-01	6.22995913E-01	2.17590094E-01
49.5	6.33822837E-01	6.33822918E-01	2.21372858E-01
50.5	6.44463813E-01	6.44463897E-01	2.25090370E-01
51.5	6.54915597E-01	6.54915690E-01	2.28741571E-01
52.5	6.65175122E-01	6.65175259E-01	2.32325464E-01
53.5	6.75239375E-01	6.75239503E-01	2.35841021E-01
54.5	6.85105401E-01	6.85105503E-01	2.39287257E-01
55.5	6.94770305E-01	6.94770455E-01	2.42663145E-01
56.5	7.04231249E-01	7.04231441E-01	2.45967746E-01
57.5	7.13485456E-01	7.13485658E-01	2.49200121E-01

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

58.5	7.22530209E-01	7.22530365E-01	2.52359301E-01
59.5	7.31362852E-01	7.31362998E-01	2.55444378E-01
60.5	7.39980794E-01	7.39980936E-01	2.58454442E-01
61.5	7.48381504E-01	7.48381674E-01	2.61388630E-01
62.5	7.56562515E-01	7.56562710E-01	2.64246047E-01
63.5	7.64521427E-01	7.64521599E-01	2.67025918E-01
64.5	7.72255902E-01	7.72256136E-01	2.69727379E-01
65.5	7.79763670E-01	7.79763937E-01	2.72349626E-01
66.5	7.87042528E-01	7.87042797E-01	2.74891943E-01
67.5	7.94090338E-01	7.94090569E-01	2.77353555E-01
68.5	8.00905031E-01	8.00905228E-01	2.79733747E-01
69.5	8.07484607E-01	8.07484806E-01	2.82031834E-01
70.5	8.13827134E-01	8.13827336E-01	2.84247100E-01
71.5	8.19930751E-01	8.19930911E-01	2.86378920E-01
72.5	8.25793665E-01	8.25793803E-01	2.88426667E-01
73.5	8.31414155E-01	8.31414282E-01	2.90389746E-01
74.5	8.36790572E-01	8.36790740E-01	2.92267561E-01
75.5	8.41921337E-01	8.41921508E-01	2.94059604E-01
76.5	8.46804944E-01	8.46805155E-01	2.95765311E-01
77.5	8.51439959E-01	8.51440132E-01	2.97384202E-01
78.5	8.55825021E-01	8.55825245E-01	2.98915774E-01
79.5	8.59958844E-01	8.59959126E-01	3.00359607E-01
80.5	8.63840213E-01	8.63840461E-01	3.01715285E-01
81.5	8.67467990E-01	8.67468238E-01	3.02982360E-01
82.5	8.70841109E-01	8.70841384E-01	3.04160506E-01
83.5	8.73958580E-01	8.73958886E-01	3.05249363E-01
84.5	8.76819487E-01	8.76819670E-01	3.06248575E-01
85.5	8.79422992E-01	8.79423141E-01	3.07157904E-01
86.5	8.81768330E-01	8.81768525E-01	3.07977051E-01
87.5	8.83854811E-01	8.83855045E-01	3.08705807E-01
88.5	8.85681825E-01	8.85682106E-01	3.09343934E-01
89.5	8.87248833E-01	8.87249112E-01	3.09891254E-01
90.5	8.88555377E-01	8.88555646E-01	3.10347587E-01
91.5	8.89601073E-01	8.89601350E-01	3.10712814E-01
92.5	8.90385614E-01	8.90385866E-01	3.10986847E-01
93.5	8.90908769E-01	8.90909016E-01	3.11169565E-01
94.5	8.91170385E-01	8.91170621E-01	3.11260939E-01
95.5	8.91170385E-01	8.91170621E-01	3.11260939E-01
96.5	8.90908769E-01	8.90908957E-01	3.11169565E-01
97.5	8.90385614E-01	8.90385747E-01	3.10986847E-01
98.5	8.89601073E-01	8.89601231E-01	3.10712844E-01
99.5	8.88555377E-01	8.88555586E-01	3.10347617E-01
100.5	8.87248833E-01	8.87249053E-01	3.09891284E-01
101.5	8.85681825E-01	8.85682046E-01	3.09343964E-01
102.5	8.83854811E-01	8.83855045E-01	3.08705837E-01
103.5	8.81768330E-01	8.81768584E-01	3.07977080E-01
104.5	8.79422992E-01	8.79423261E-01	3.07157904E-01
105.5	8.76819487E-01	8.76819730E-01	3.06248575E-01
106.5	8.73958580E-01	8.73958826E-01	3.05249333E-01
107.5	8.70841109E-01	8.70841324E-01	3.04160476E-01
108.5	8.67467990E-01	8.67468238E-01	3.02982360E-01
109.5	8.63840213E-01	8.63840461E-01	3.01715285E-01
110.5	8.59958844E-01	8.59959126E-01	3.00359637E-01
111.5	8.55825021E-01	8.55825305E-01	2.98915803E-01
112.5	8.51439959E-01	8.51440251E-01	2.97384232E-01

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

113.5	8.46804944E-01	8.46805215E-01	2.95765340E-01
114.5	8.41921337E-01	8.41921568E-01	2.94059634E-01
115.5	8.36790572E-01	8.36790800E-01	2.92267591E-01
116.5	8.31414155E-01	8.31414342E-01	2.90389746E-01
117.5	8.25793665E-01	8.25793862E-01	2.88426667E-01
118.5	8.19930751E-01	8.19930971E-01	2.86378920E-01
119.5	8.13827134E-01	8.13827395E-01	2.84247071E-01
120.5	8.07484607E-01	8.07484865E-01	2.82031804E-01
121.5	8.00905031E-01	8.00905287E-01	2.79733747E-01
122.5	7.94090338E-01	7.94090629E-01	2.77353555E-01
123.5	7.87042528E-01	7.87042797E-01	2.74891943E-01
124.5	7.79763670E-01	7.79763877E-01	2.72349626E-01
125.5	7.72255902E-01	7.72256076E-01	2.69727379E-01
126.5	7.64521427E-01	7.64521599E-01	2.67025918E-01
127.5	7.56562515E-01	7.56562710E-01	2.64246047E-01
128.5	7.48381504E-01	7.48381674E-01	2.61388630E-01
129.5	7.39980794E-01	7.39980936E-01	2.58454442E-01
130.5	7.31362852E-01	7.31362998E-01	2.55444407E-01
131.5	7.22530209E-01	7.22530365E-01	2.52359331E-01
132.5	7.13485456E-01	7.13485599E-01	2.49200135E-01
133.5	7.04231249E-01	7.04231381E-01	2.45967790E-01
134.5	6.94770305E-01	6.94770396E-01	2.42663175E-01
135.5	6.85105401E-01	6.85105503E-01	2.39287272E-01
136.5	6.75239375E-01	6.75239503E-01	2.35841051E-01
137.5	6.65175122E-01	6.65175319E-01	2.32325479E-01
138.5	6.54915597E-01	6.54915810E-01	2.28741586E-01
139.5	6.44463813E-01	6.44463956E-01	2.25090370E-01
140.5	6.33822837E-01	6.33822918E-01	2.21372873E-01
141.5	6.22995793E-01	6.22995913E-01	2.17590109E-01
142.5	6.11985860E-01	6.11985981E-01	2.13743061E-01
143.5	6.00796269E-01	6.00796402E-01	2.09832743E-01
144.5	5.89430307E-01	5.89430451E-01	2.05860153E-01
145.5	5.77891308E-01	5.77891469E-01	2.01826230E-01
146.5	5.66182661E-01	5.66182792E-01	1.97731853E-01
147.5	5.54307803E-01	5.54307938E-01	1.93577841E-01
148.5	5.42270220E-01	5.42270362E-01	1.89364925E-01
149.5	5.30073445E-01	5.30073583E-01	1.85093641E-01
150.5	5.17721060E-01	5.17721176E-01	1.80764362E-01
151.5	5.05216691E-01	5.05216837E-01	1.76377177E-01
152.5	4.92564007E-01	4.92564112E-01	1.71931788E-01
153.5	4.79766725E-01	4.79766846E-01	1.67427436E-01
154.5	4.66828600E-01	4.66828704E-01	1.62862688E-01
155.5	4.53753431E-01	4.53753531E-01	1.58235282E-01
156.5	4.40545056E-01	4.40545171E-01	1.53541774E-01
157.5	4.27207353E-01	4.27207500E-01	1.48777142E-01
158.5	4.13744236E-01	4.13744390E-01	1.43934369E-01
159.5	4.00159659E-01	4.00159836E-01	1.39003754E-01
160.5	3.86457610E-01	3.86457831E-01	1.33972004E-01
161.5	3.72642110E-01	3.72642398E-01	1.28821090E-01
162.5	3.58717216E-01	3.58717591E-01	1.23526692E-01
163.5	3.44687015E-01	3.44687492E-01	1.18056223E-01
164.5	3.30555627E-01	3.30556273E-01	1.12366058E-01
165.5	3.16327199E-01	3.16328108E-01	1.06398046E-01
166.5	3.02005908E-01	3.02007228E-01	1.00074753E-01
167.5	2.87595960E-01	2.87597865E-01	9.32932720E-02

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

168.5	2.73101583E-01	2.73104340E-01	8.59168991E-02
169.5	2.58527034E-01	2.58531034E-01	7.77643397E-02
170.5	2.43925844E-01	2.43882447E-01	6.86637014E-02
171.5	2.29589210E-01	2.29548544E-01	6.06838576E-02
172.5	2.15548851E-01	2.15510845E-01	5.36243916E-02
173.5	2.01786649E-01	2.01751217E-01	4.73695807E-02
174.5	1.88284845E-01	1.88251913E-01	4.18178216E-02
175.5	1.75026014E-01	1.74995512E-01	3.68797928E-02
176.5	1.61993047E-01	1.61964908E-01	3.24768946E-02
177.5	1.49169125E-01	1.49143293E-01	2.85398830E-02
178.5	1.36537700E-01	1.36514112E-01	2.50076354E-02
179.5	1.24082472E-01	1.24061085E-01	2.18260773E-02
180.5	1.11787366E-01	1.11768141E-01	1.89472437E-02
181.5	9.96365180E-02	9.96194258E-02	1.63284279E-02
182.5	8.76142465E-02	8.75992402E-02	1.39314411E-02
183.5	7.57050374E-02	7.56920949E-02	1.17219435E-02
184.5	6.38935227E-02	6.38826117E-02	9.66884382E-03
185.5	5.21644598E-02	5.21555655E-02	7.74376141E-03
186.5	4.05027131E-02	4.04958092E-02	5.92053263E-03
187.5	2.88932335E-02	2.88883150E-02	4.17475263E-03
188.5	1.73210393E-02	1.73180923E-02	2.48335744E-03
189.5	5.77119728E-03	5.77021576E-03	8.24221934E-04

Largest difference in neutron flux = 0.0178336985%

Verification, Validation, and Benchmarking Report for AXLIB4 (U)**Fig. A.2: Relative Neutron Fluxes vs. Axial Positions**

APPENDIX B

DATA & RESULTS FOR PROBLEM 2

B.1 GEOMETRY

0.0 x_L

Assembly length = x_L = 150.0 inches
Number of mesh = 150; Mesh size = 1.0 inch

B.2 PHYSICS DATA

	TWO-GROUP CROSS SECTIONS	
	GROUP 1	GROUP 2
Diffusion (cm)	1.41630	0.93179
Removal (/cm)	0.01054	0.01975
Capture (/cm)	0.00147	0.01141
Fission (/cm)	0.00094	0.00834
Nu*fission (/cm)	0.00230	0.02028
Scatt. 1-> (/cm)	0.00000	0.00813
Scatt. 2-> (/cm)	0.00000	0.00000
Velocity (cm/s)	9.918079E+6	3.39764E+5
Safety rod abs. (/cm)	0.00000	0.00141

GROUP	DELAY NEUTRON PRECURSORS	
	FRACTIONS	DECAY CONSTANT (/sec)
1	9.7320E-5	1.0530E-4
2	1.7113E-3	2.4850E-2
3	1.1869E-3	1.1500E-1
4	3.1717E-3	3.0600E-1
5	9.2123E-4	1.4000E+0
6	2.0261E-4	3.8700E+0

B.3 RESULTS

FISSION CORRECTION FACTORS

	AXLIB4	ANALYTICAL	%DIFFERENT
Ave. Eff. Multi. Factor	0.99860434	0.99860700	2.66371E-4
Ave. Fiss. Corec. Factor	1.00139761	1.00139494	2.66628E-4

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

FISSION CORRECTION FACTORS VS. AXIAL POSITIONS (AXLIB4)

X (IN.)	F.C.	X (IN.)	F.C.	X (IN.)	F.C.
0.5	1.00139546	1.5	1.00139546	2.5	1.00139546
3.5	1.00139558	4.5	1.00139582	5.5	1.00139570
6.5	1.00139570	7.5	1.00139570	8.5	1.00139558
9.5	1.00139558	10.5	1.00139558	11.5	1.00139570
12.5	1.00139546	13.5	1.00139546	14.5	1.00139546
15.5	1.00139558	16.5	1.00139534	17.5	1.00139546
18.5	1.00139534	19.5	1.00139546	20.5	1.00139558
21.5	1.00139570	22.5	1.00139582	23.5	1.00139594
24.5	1.00139582	25.5	1.00139594	26.5	1.00139594
27.5	1.00139582	28.5	1.00139594	29.5	1.00139618
30.5	1.00139630	31.5	1.00139630	32.5	1.00139642
33.5	1.00139642	34.5	1.00139654	35.5	1.00139666
36.5	1.00139678	37.5	1.00139689	38.5	1.00139678
39.5	1.00139701	40.5	1.00139701	41.5	1.00139701
42.5	1.00139713	43.5	1.00139713	44.5	1.00139713
45.5	1.00139713	46.5	1.00139713	47.5	1.00139701
48.5	1.00139725	49.5	1.00139737	50.5	1.00139737
51.5	1.00139737	52.5	1.00139749	53.5	1.00139737
54.5	1.00139725	55.5	1.00139737	56.5	1.00139737
57.5	1.00139725	58.5	1.00139737	59.5	1.00139737
60.5	1.00139725	61.5	1.00139725	62.5	1.00139725
63.5	1.00139713	64.5	1.00139713	65.5	1.00139713
66.5	1.00139725	67.5	1.00139725	68.5	1.00139725
69.5	1.00139725	70.5	1.00139713	71.5	1.00139725
72.5	1.00139725	73.5	1.00139725	74.5	1.00139713
75.5	1.00139725	76.5	1.00139725	77.5	1.00139713
78.5	1.00139713	79.5	1.00139713	80.5	1.00139713
81.5	1.00139725	82.5	1.00139713	83.5	1.00139725
84.5	1.00139713	85.5	1.00139713	86.5	1.00139713
87.5	1.00139701	88.5	1.00139713	89.5	1.00139701
90.5	1.00139701	91.5	1.00139713	92.5	1.00139689
93.5	1.00139689	94.5	1.00139701	95.5	1.00139689
96.5	1.00139701	97.5	1.00139689	98.5	1.00139701
99.5	1.00139701	100.5	1.00139689	101.5	1.00139701
102.5	1.00139725	103.5	1.00139725	104.5	1.00139713
105.5	1.00139725	106.5	1.00139713	107.5	1.00139713
108.5	1.00139713	109.5	1.00139713	110.5	1.00139713
111.5	1.00139713	112.5	1.00139701	113.5	1.00139713
114.5	1.00139713	115.5	1.00139725	116.5	1.00139701
117.5	1.00139701	118.5	1.00139701	119.5	1.00139689
120.5	1.00139701	121.5	1.00139701	122.5	1.00139713
123.5	1.00139701	124.5	1.00139713	125.5	1.00139701
126.5	1.00139725	127.5	1.00139725	128.5	1.00139725
129.5	1.00139713	130.5	1.00139725	131.5	1.00139725
132.5	1.00139749	133.5	1.00139749	134.5	1.00139749
135.5	1.00139749	136.5	1.00139773	137.5	1.00139785
138.5	1.00139809	139.5	1.00139844	140.5	1.00139880
141.5	1.00139940	142.5	1.00140011	143.5	1.00140142
144.5	1.00140321	145.5	1.00140643	146.5	1.00141156

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

147.5 1.00142133 148.5 1.00144517 149.5 1.00156832

Fig. B.1: Fission Correction Factors vs. Axial Positions

COMPARISON OF FLUX PROFILES

x(in.)	ANALYTICAL FLUX1	AXLIB4 FLUX1	ANALYTICAL FLUX2	AXLIB4 FLUX2
0.5	2.51040413E-02	2.51035672E-02	1.03009246E-02	1.03007285E-02
1.5	7.53011126E-02	7.52996951E-02	3.08982554E-02	3.08976714E-02
2.5	1.25465154E-01	1.25462800E-01	5.14820333E-02	5.14810607E-02
3.5	1.75574163E-01	1.75570861E-01	7.20432294E-02	7.20418617E-02
4.5	2.25606159E-01	2.25601941E-01	9.25728250E-02	9.25710648E-02
5.5	2.75539196E-01	2.75534034E-01	1.13061815E-01	1.13059670E-01
6.5	3.25351373E-01	3.25345248E-01	1.33501213E-01	1.33498669E-01
7.5	3.75020840E-01	3.75013769E-01	1.53882052E-01	1.53879121E-01
8.5	4.24525811E-01	4.24517781E-01	1.74195394E-01	1.74192086E-01
9.5	4.73844570E-01	4.73835617E-01	1.94432327E-01	1.94428667E-01
10.5	5.22955486E-01	5.22945642E-01	2.14583977E-01	2.14579925E-01
11.5	5.71837016E-01	5.71826279E-01	2.34641502E-01	2.34637082E-01

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

12.5	6.20467719E-01	6.20456100E-01	2.54596107E-01	2.54591316E-01
13.5	6.68826265E-01	6.68813705E-01	2.74439037E-01	2.74433881E-01
14.5	7.16891442E-01	7.16877997E-01	2.94161588E-01	2.94156075E-01
15.5	7.64642166E-01	7.64627874E-01	3.13755111E-01	3.13749194E-01
16.5	8.12057493E-01	8.12042296E-01	3.33211011E-01	3.33204746E-01
17.5	8.59116624E-01	8.59100521E-01	3.52520753E-01	3.52514088E-01
18.5	9.05798919E-01	9.05781925E-01	3.71675868E-01	3.71668816E-01
19.5	9.52083900E-01	9.52065945E-01	3.90667954E-01	3.90660554E-01
20.5	9.97951266E-01	9.97932374E-01	4.09488679E-01	4.09480870E-01
21.5	1.04338090E+00	1.04336107E+00	4.28129790E-01	4.28121567E-01
22.5	1.08835287E+00	1.08833218E+00	4.46583108E-01	4.46574479E-01
23.5	1.13284745E+00	1.13282585E+00	4.64840541E-01	4.64831531E-01
24.5	1.17684513E+00	1.17682266E+00	4.82894079E-01	4.82884705E-01
25.5	1.22032660E+00	1.22030330E+00	5.00735804E-01	5.00726044E-01
26.5	1.26327280E+00	1.26324856E+00	5.18357889E-01	5.18347740E-01
27.5	1.30566489E+00	1.30563986E+00	5.35752606E-01	5.35742104E-01
28.5	1.34748427E+00	1.34745824E+00	5.52912324E-01	5.52901447E-01
29.5	1.38871260E+00	1.38868570E+00	5.69829516E-01	5.69818258E-01
30.5	1.42933179E+00	1.42930400E+00	5.86496762E-01	5.86485088E-01
31.5	1.46932403E+00	1.46929526E+00	6.02906751E-01	6.02894664E-01
32.5	1.50867177E+00	1.50864220E+00	6.19052285E-01	6.19039834E-01
33.5	1.54735777E+00	1.54732716E+00	6.34926283E-01	6.34913445E-01
34.5	1.58536504E+00	1.58533347E+00	6.50521781E-01	6.50508583E-01
35.5	1.62267691E+00	1.62264442E+00	6.65831939E-01	6.65818393E-01
36.5	1.65927703E+00	1.65924358E+00	6.80850040E-01	6.80836082E-01
37.5	1.69514933E+00	1.69511509E+00	6.95569499E-01	6.95555210E-01
38.5	1.73027809E+00	1.73024297E+00	7.09983857E-01	7.09969282E-01
39.5	1.76464789E+00	1.76461196E+00	7.24086794E-01	7.24071860E-01
40.5	1.79824365E+00	1.79820704E+00	7.37872121E-01	7.37856865E-01
41.5	1.83105065E+00	1.83101344E+00	7.51333794E-01	7.51318276E-01
42.5	1.86305448E+00	1.86301649E+00	7.64465907E-01	7.64450073E-01
43.5	1.89424112E+00	1.89420235E+00	7.77262700E-01	7.77246535E-01
44.5	1.92459688E+00	1.92455745E+00	7.89718560E-01	7.89702177E-01
45.5	1.95410845E+00	1.95406842E+00	8.01828023E-01	8.01811337E-01
46.5	1.98276289E+00	1.98272216E+00	8.13585778E-01	8.13568830E-01
47.5	2.01054762E+00	2.01050615E+00	8.24986667E-01	8.24969471E-01
48.5	2.03745045E+00	2.03740835E+00	8.36025690E-01	8.36008191E-01
49.5	2.06345960E+00	2.06341696E+00	8.46698004E-01	8.46680224E-01
50.5	2.08856364E+00	2.08852053E+00	8.56998929E-01	8.56980920E-01
51.5	2.11275157E+00	2.11270809E+00	8.66923945E-01	8.66905808E-01
52.5	2.13601277E+00	2.13596869E+00	8.76468700E-01	8.76450360E-01
53.5	2.15833705E+00	2.15829253E+00	8.85629007E-01	8.85610521E-01
54.5	2.17971461E+00	2.17966962E+00	8.94400848E-01	8.94382179E-01
55.5	2.20013608E+00	2.20009065E+00	9.02780375E-01	9.02761519E-01
56.5	2.21959250E+00	2.21954679E+00	9.10763912E-01	9.10744905E-01
57.5	2.23807532E+00	2.23802948E+00	9.18347959E-01	9.18328881E-01
58.5	2.25557646E+00	2.25553036E+00	9.25529188E-01	9.25509930E-01
59.5	2.27208822E+00	2.27204180E+00	9.32304449E-01	9.32285070E-01
60.5	2.28760337E+00	2.28755689E+00	9.38670770E-01	9.38651264E-01
61.5	2.30211510E+00	2.30206847E+00	9.44625360E-01	9.44605768E-01
62.5	2.31561705E+00	2.31556988E+00	9.50165605E-01	9.50145900E-01
63.5	2.32810330E+00	2.32805586E+00	9.55289077E-01	9.55269337E-01
64.5	2.33956835E+00	2.33952069E+00	9.59993527E-01	9.59973693E-01
65.5	2.35000720E+00	2.34995937E+00	9.64276892E-01	9.64257002E-01
66.5	2.35941526E+00	2.35936737E+00	9.68137294E-01	9.68117297E-01

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

67.5	2.36778840E+00	2.36773992E+00	9.71573039E-01	9.71552908E-01
68.5	2.37512295E+00	2.37507439E+00	9.74582619E-01	9.74562407E-01
69.5	2.38141569E+00	2.38136697E+00	9.77164715E-01	9.77144480E-01
70.5	2.38666386E+00	2.38661528E+00	9.79318195E-01	9.79297936E-01
71.5	2.39086517E+00	2.39081645E+00	9.81042113E-01	9.81021821E-01
72.5	2.39401776E+00	2.39396906E+00	9.82335714E-01	9.82315361E-01
73.5	2.39612025E+00	2.39607143E+00	9.83198430E-01	9.83178079E-01
74.5	2.39717173E+00	2.39712286E+00	9.83629883E-01	9.83609498E-01
75.5	2.39717173E+00	2.39712286E+00	9.83629883E-01	9.83609438E-01
76.5	2.39612025E+00	2.39607143E+00	9.83198430E-01	9.83177960E-01
77.5	2.39401776E+00	2.39396882E+00	9.82335714E-01	9.82315242E-01
78.5	2.39086517E+00	2.39081621E+00	9.81042113E-01	9.81021643E-01
79.5	2.38666386E+00	2.38661504E+00	9.79318195E-01	9.79297698E-01
80.5	2.38141569E+00	2.38136673E+00	9.77164715E-01	9.77144241E-01
81.5	2.37512295E+00	2.37507415E+00	9.74582619E-01	9.74562168E-01
82.5	2.36778840E+00	2.36773968E+00	9.71573038E-01	9.71552670E-01
83.5	2.35941526E+00	2.35936666E+00	9.68137294E-01	9.68116999E-01
84.5	2.35000720E+00	2.34995866E+00	9.64276892E-01	9.64256644E-01
85.5	2.33956835E+00	2.33951998E+00	9.59993527E-01	9.59973335E-01
86.5	2.32810329E+00	2.32805538E+00	9.55289077E-01	9.55269039E-01
87.5	2.31561705E+00	2.31556940E+00	9.50165605E-01	9.50145662E-01
88.5	2.30211510E+00	2.30206752E+00	9.44625360E-01	9.44605470E-01
89.5	2.28760337E+00	2.28755593E+00	9.38670770E-01	9.38650966E-01
90.5	2.27208822E+00	2.27204108E+00	9.32304449E-01	9.32284772E-01
91.5	2.25557646E+00	2.25552940E+00	9.25529188E-01	9.25509632E-01
92.5	2.23807532E+00	2.23802853E+00	9.18347959E-01	9.18328583E-01
93.5	2.21959249E+00	2.21954608E+00	9.10763912E-01	9.10744667E-01
94.5	2.20013608E+00	2.20008993E+00	9.02780375E-01	9.02761221E-01
95.5	2.17971461E+00	2.17966890E+00	8.94400848E-01	8.94381881E-01
96.5	2.15833705E+00	2.15829158E+00	8.85629007E-01	8.85610163E-01
97.5	2.13601277E+00	2.13596773E+00	8.76468700E-01	8.76449943E-01
98.5	2.11275157E+00	2.11270690E+00	8.66923945E-01	8.66905391E-01
99.5	2.08856364E+00	2.08851933E+00	8.56998928E-01	8.56980503E-01
100.5	2.06345960E+00	2.06341577E+00	8.46698004E-01	8.46679807E-01
101.5	2.03745045E+00	2.03740716E+00	8.36025690E-01	8.36007655E-01
102.5	2.01054762E+00	2.01050496E+00	8.24986667E-01	8.24968874E-01
103.5	1.98276289E+00	1.98272061E+00	8.13585777E-01	8.13568234E-01
104.5	1.95410845E+00	1.95406687E+00	8.01828023E-01	8.01810741E-01
105.5	1.92459688E+00	1.92455602E+00	7.89718559E-01	7.89701521E-01
106.5	1.89424112E+00	1.89420092E+00	7.77262700E-01	7.77245939E-01
107.5	1.86305448E+00	1.86301494E+00	7.64465907E-01	7.64449477E-01
108.5	1.83105065E+00	1.83101189E+00	7.51333794E-01	7.51317680E-01
109.5	1.79824365E+00	1.79820573E+00	7.37872121E-01	7.37856269E-01
110.5	1.76464789E+00	1.76461077E+00	7.24086793E-01	7.24071264E-01
111.5	1.73027809E+00	1.73024178E+00	7.09983857E-01	7.09968686E-01
112.5	1.69514933E+00	1.69511390E+00	6.95569498E-01	6.95554674E-01
113.5	1.65927703E+00	1.65924239E+00	6.80850040E-01	6.80835485E-01
114.5	1.62267691E+00	1.62264311E+00	6.65831938E-01	6.65817738E-01
115.5	1.58536504E+00	1.58533204E+00	6.50521781E-01	6.50507927E-01
116.5	1.54735777E+00	1.54732561E+00	6.34926283E-01	6.34912848E-01
117.5	1.50867177E+00	1.50864053E+00	6.19052285E-01	6.19039237E-01
118.5	1.46932403E+00	1.46929359E+00	6.02906751E-01	6.02894127E-01
119.5	1.42933179E+00	1.42930222E+00	5.86496762E-01	5.86484551E-01
120.5	1.38871259E+00	1.38868403E+00	5.69829515E-01	5.69817662E-01
121.5	1.34748427E+00	1.34745669E+00	5.52912323E-01	5.52900851E-01

Verification, Validation, and Benchmarking Report for AXLIB4 (U)

122.5	1.30566489E+00	1.30563831E+00	5.35752605E-01	5.35741508E-01
123.5	1.26327280E+00	1.26324725E+00	5.18357889E-01	5.18347204E-01
124.5	1.22032660E+00	1.22030199E+00	5.00735803E-01	5.00725567E-01
125.5	1.17684513E+00	1.17682159E+00	4.82894079E-01	4.82884318E-01
126.5	1.13284745E+00	1.13282502E+00	4.64840541E-01	4.64831173E-01
127.5	1.08835287E+00	1.08833146E+00	4.46583108E-01	4.46574181E-01
128.5	1.04338090E+00	1.04336047E+00	4.28129790E-01	4.28121299E-01
129.5	9.97951265E-01	9.97931957E-01	4.09488679E-01	4.09480631E-01
130.5	9.52083899E-01	9.52065706E-01	3.90667953E-01	3.90660346E-01
131.5	9.05798918E-01	9.05781865E-01	3.71675868E-01	3.71668667E-01
132.5	8.59116623E-01	8.59100640E-01	3.52520753E-01	3.52513999E-01
133.5	8.12057492E-01	8.12042654E-01	3.33211011E-01	3.33204716E-01
134.5	7.64642165E-01	7.64628410E-01	3.13755111E-01	3.13749284E-01
135.5	7.16891441E-01	7.16878712E-01	2.94161588E-01	2.94156224E-01
136.5	6.68826264E-01	6.68814659E-01	2.74439036E-01	2.74434119E-01
137.5	6.20467718E-01	6.20457232E-01	2.54596106E-01	2.54591644E-01
138.5	5.71837015E-01	5.71827650E-01	2.34641502E-01	2.34637499E-01
139.5	5.22955485E-01	5.22947252E-01	2.14583976E-01	2.14580417E-01
140.5	4.73844569E-01	4.73837405E-01	1.94432327E-01	1.94429189E-01
141.5	4.24525810E-01	4.24519718E-01	1.74195393E-01	1.74192667E-01
142.5	3.75020839E-01	3.75015736E-01	1.53882052E-01	1.53879732E-01
143.5	3.25351372E-01	3.25347215E-01	1.33501212E-01	1.33499295E-01
144.5	2.75539195E-01	2.75535941E-01	1.13061815E-01	1.13060266E-01
145.5	2.25606158E-01	2.25603744E-01	9.25728246E-02	9.25716087E-02
146.5	1.75574162E-01	1.75572500E-01	7.20432290E-02	7.20423236E-02
147.5	1.25465153E-01	1.25464156E-01	5.14820329E-02	5.14814183E-02
148.5	7.53011116E-02	7.53006414E-02	3.08982550E-02	3.08978967E-02
149.5	2.51040404E-02	2.51039527E-02	1.03009242E-02	1.03008067E-02

Largest difference in neutron flux1 = 0.00213237805%

Largest difference in neutron flux2 = 0.00215747743%

Fig. B.2: Relative Neutron Fluxes vs. Axial Positions

Verification, Validation, and Benchmarking Report for AXLIB4 (U)**COMPARISON OF POWER DECAY****Fig. B.3: Decay Power vs. Time**

References

References

1. R. E. Pevey, Axial Power Profiles in SRP Reactors During LOCA, DPST-87-511, June 26, 1987.
2. M. V. Gregory, Users Guide to the "DPOSIT OPTION" in LLAP, WSRC-RP-89-998, October 1989.
3. R. E. Pevey, Benchmarking Report for WIGGLE (A One-Dimensional Transient Diffusion Theory Code), WSRC-TR-90-189, November 1990.
4. S. E. Aleman, M.V. Gregory, L. L. Hamm, L. D. Koffman, R. E. Pevey, W. H. Reed, F. G. Smith, FLOWTRAN: An Algorithm for Describing the Thermal-Hydraulic Behavior of SRP Assemblies (U), DPSTM-140, September 15, 1989.
5. H. Toffer, R. D. Crowe, K. N. Schwinkendorf, R. E. Pevey, Verification and Validation Plan for Reactor Analysis Computer Code (U), WSRC-RP-89-1249, November, 1989.

**DATE
FILMED**

8 / 16 / 93

END