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FAST BREEDER REACTOR
STATIC PHYSICS METHODS DEVELOPMENT
AND ANALYSIS PROJECT

— Quarterly Technical Report —

July - September 1968

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— Quarterly Technical Report —

July - September 1968

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1. INTRODUCTION

In March 1967, Babcock & Wilcox (B&W) initiated a program of analytical methods development applicable to the physics design of fast breeder reactors. One phase of this effort has as its goal the development and utilization of a design-oriented, one-dimensional criticality and depletion code applicable to the physics analysis of fast reactors. This phase of the methods development effort is under full sponsorship of the U.S. Atomic Energy Commission (AEC). Utilization of the code will consist of an investigation in which the design code FARED will be used to relate the sensitivity of certain fast reactor design parameters to the complexity of the physics model used to evaluate them. Finally, several fast reactor critical experiments will be analyzed to verify the applicability of the code and its cross-section libraries. Future topics of study under the FARED project include (1) extension of the criticality and depletion segments to two dimensions with provision for complex fuel management studies, and (2) study of the importance of generating multigroup cross sections using space-dependent spectrum weighting.

In April 1968, a sensitivity study relating to burnup and fuel management in fast reactors was initiated as Task 4 of the FARED project. The objectives of this study are described in the third quarterly progress report (BAW-3867-3).¹

This fifth quarterly report for the FARED project covers work done during the period July - September 1968. Major accomplishments during this period may be summarized as follows:

1. Modifications to the RETAP program to include source and depletion data files were initiated, and programming of a complete edit routine was continued.

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¹Roy, D. H., Babcock & Wilcox, BAW-3867-3, April 1968.

2. Programming of the REGA spectrum routine continued, and coupling with STRIP and UNRES was initiated.
3. A detailed overlay structure was specified, and reformulation of the criticality search routines in RAIM was begun.
4. Depletion calculations for the 2000- and 8000-liter cores were completed using the reference and modified libraries.

2. FARED CODE DEVELOPMENT

2.1. FARED Control and Overlay Structure

The basic overlay structure of the FARED Code is diagrammed in Figure 2-1. Overall control of the code is maintained by the main overlay EXEC. This program has the responsibility for recognizing certain directives and calling the appropriate primary overlays. Program EXEC is designed to control the calculational flow of the FARED Code, but does not perform any computations directly.

EXEC calls a group of subroutines which read and interpret the various directives and data. This capability is also available to all primary overlays because these subroutines, together with the main overlay EXEC, remain in core storage at all times.

INPUT is a primary overlay which is called from EXEC to read reactor configuration data. This program interprets all directives that describe the reactor configuration and sets up storage locations and disk files to systematically store all configuration data. INPUT returns control to EXEC, which interprets the next directives.

REGA CONTROL is a primary overlay which is called from EXEC to calculate poly-group microscopic cross sections. All data necessary for these calculations are available from INPUT or the RETAP library tape. REGA CONTROL calls the secondary overlays UNRES, STRIP, and SPECTRUM to perform the cross-section calculations, and writes a REGA library tape which contains the microscopic cross sections and other pertinent nuclide data. These cross sections, as well as associated resonance parameters, may be printed by a directive calling REGA EDIT.

The third primary overlay, RAIM CONTROL, is responsible for sequencing criticality, depletion, and edit calculations. This program is called from EXEC whenever directives initiating flux or edit calculations are encountered. In addition, RAIM CONTROL sequences a series of flux, depletion, and edit calculations when a depletion directive is

Figure 2-1. FARED Overlay Structure

recognized. There are six basic secondary overlays which perform the RAIM calculations.

The first four perform the criticality calculation. MACRO computes the zone- and group-dependent macroscopic cross sections from data on the REGA library tape. These cross sections are used by CONS to compute the coefficients necessary to perform the eigenvalue-flux calculation in FLUX. The fourth secondary overlay, CRIT, performs the various criticality searches as specified by the appropriate directives.

Zone-material depletion is performed by the overlay REDEP. This program depletes each nuclide concentration in the reactor according to its position in the decay chain matrix specified on the RETAP library tape. At the end of a depletion period, the nuclide concentrations specified in COMMON storage are updated, and control is returned to RAIM CONTROL.

The final secondary overlay called by RAIM CONTROL is the RAIM EDIT program, which calculates and prints a wide variety of edits according to specified directives. RAIM EDIT may be called in conjunction with a specific depletion sequence or individually from EXEC.

The main overlay and the three primary overlays, which have been discussed, make up the basic FARED Code. However, a fourth secondary, MANAGE, is being formulated as a part of a more sophisticated FARED Code. This program is designed to automate fuel management in the reactor, allow external fuel management, reprocessing and fabrication, and calculate fuel cycle costs. Although automated fuel management is not proposed for the basic FARED Code, any management scheme may be accomplished with individual directives specifying the appropriate changes in the reactor configuration.

2.2. Input Routine

The directives that define the reactor configuration are read by the overlay INPUT. The list of directives that INPUT interprets have been described, in part, in the fourth quarterly progress report.² There

- - - - -

²Roy, D. H., Babcock & Wilcox, BAW-3867-4, September 1968.

are, however, four additional categories of configuration data as described below.

2.2.1. Source Data

Values of the starting source must be specified for the initial reactor configuration. The directives SOURCE, ZSOURCE, or PTSOURCE indicate that the source distribution is considered as constant, zone-dependent or point-dependent, respectively. The appropriate source values are listed after the directive describing the desired source distribution. If the source directive is omitted, the directive SOURCE, with a single value of unity, is assumed.

2.2.2. Transverse Buckling Data

Appropriate values for the transverse buckling are input by a buckling directive. The buckling is specified as constant, zone-dependent, group-dependent or zone- and group-dependent according to the directives BUCK, ZBUCK, GBUCK, or ZGBUCK, respectively. Appropriate buckling values are listed following the desired directive. A value of zero for the zone- and group-dependent transverse buckling is assumed if no buckling directive is encountered.

2.2.3. Extrapolation Lengths

If extrapolation lengths are required for the boundary condition options chosen, they are input through extrapolation length directives. The group-dependent extrapolation lengths at the inner and outer boundaries are specified by INNER and OUTER directives, respectively. Either directive is followed by values of the extrapolation lengths for each energy group.

2.2.4. Poly-Group Structure

The correspondence between the fine-group structure of the microscopic cross sections on the RETAP library tape and the desired poly-group structure for the REGA library tape must be specified. A POLY directive indicates that a list of integers representing the lower poly-group limits is to follow. There must be a fine-group number for each group in the poly-group structure.

To illustrate the use of the foregoing directives, an extension of the three-zone reactor described in the fourth quarterly progress report is given:

ZSOURCE	1.0	1.0	0.5			
ZBUCK	0.009	0.009	0.004			
OUTER	0.9	0.9	0.9	0.8	0.8	0.8
	0.8	0.7	0.7	0.7	0.7	0.7
	0.6	0.6	0.6	0.6	0.5	0.5
	0.5	0.4	0.4	0.4	0.3	0.3
	0.3	0.2	0.2	0.1	0.1	0.1
POLY	2	4	6	8	10	13
	15	17	20	22	24	26
	29	31	33	35	38	40
	42	44	46	48	51	53
	55	58	61	63	65	68

Card 1

ZSOURCE indicates that starting source values are given for each reactor zone.

1.0 1.0 0.5 are the source values in zones 1, 2, and 3, respectively.

Card 2

ZBUCK indicates that the transverse buckling is zone-dependent and group-independent.

0.009 0.009 0.004 are the buckling values for all energy groups in zones 1, 2, and 3, respectively.

Card 3

OUTER indicates that values of the group-dependent outer extrapolation lengths are listed.

0.9 0.9 0.9 0.8 0.8 0.8 are the outer extrapolation lengths for groups one through six, respectively.

Cards 4 - 7

Values of the outer extrapolation lengths are listed for the remaining energy groups.

Card 8

POLY indicates that the poly-group structure numbers are to follow.

2 4 6 8 10 13 are the fine-group numbers corresponding to the first six poly-group boundaries.

Cards 9 - 12

Fine-group numbers for the remaining poly-group boundaries are listed.

The example just given is intended only to illustrate the use of the various directives, and does not necessarily represent a realistic problem.

2.3. Operational Directives

All directives discussed previously have been used to input reactor configuration data. There is another set of directives which is used to specify the operations to be performed by the FARED Code. These operational directives are interpreted by EXEC, REGA CONTROL, and RAIM CONTROL in order to organize sequences of calculations. The primary operational directives are divided into six categories as follows:

1. REGA specifies that a microscopic cross-section calculation is to be performed by the REGA program for each distinct reactor block. All data necessary for this calculation are specified in the reactor configuration data and on the RETAP library tape. No additional information is needed for execution of the REGA program. The output from REGA is in the form of a REGA library tape for use in the flux, depletion, and edit calculations.

2. RAIM indicates that an eigenvalue-flux calculation is to be performed by the RAIM program. No additional information is required unless a criticality search is desired in conjunction with the flux calculation. Any one of several criticality searches may be specified by a SEARCH directive.

3. SEARCH defines a criticality search to be performed in conjunction with the flux calculation. The particular type of search,

together with pertinent search data, is specified following this directive. Search option directives include COMPOSITION, DIMENSION, and BUCKLING.

4. EDIT indicates that an EDIT program is to be called which will perform specified edit calculations. All printed output is initiated by this directive. The desired edits are listed after this directive, each with its associated data, if required. The list of edit names includes NEUTRONICS, ZONE, SECTION, REACTOR, ZONE-MATERIAL, ADJOINT, and PERTURBATION.

5. DEplete specifies that one or more depletion calculations are to be performed. This directive sets up a series of flux, depletion, and edit calculations as specified by the data following the DEplete directive. These data define the number and length of the depletion periods, as well as the particular edits that are to be performed. Various criticality searches and tests may be executed at the end of each depletion period with the inclusion of appropriate TEST directives.

6. TEST indicates that the values of certain quantities are to be investigated at the end of each depletion period. Composition, dimension, and buckling searches may be performed to maintain a specified value of k_{eff} . In addition, values of k_{eff} , particular nuclide concentrations, or the burnup of specified zone materials may be compared with their associated default values to terminate the depletion sequence.

A continuation of the three-zone reactor example is given to illustrate the use of the various operational directives:

REGA	REGRES	REGMICRO
RAIM		
SEARCH	COMPOSITION	ZM1 1.002
EDIT	NEUTRONICS	ZONE REACTOR
DEplete	0.0 8 50.0 5	ZONE-MATERIAL REACTOR
TEST	CONTROL	ZM8 1.002
	IMINIMUM	TA82 0.0 ZM8
	BMAXIMUM	33000.0 ZM1
EDIT	NEUTRONICS	ZONE SECTION

Card 1

REGA

initiates the microscopic cross section calculations by the REGA program. The cross sections and other pertinent nuclide data are written on the REGA library tape.

REGRES initiates the printing of the resonance parameters calculated by REGA.

REGMICRO indicates that the microscopic cross sections are to be printed.

Card 2

RAIM

initiates the eigenvalue-flux calculation.

Card 3

SEARCH

indicates that a criticality search is to be performed during the flux calculation.

COMPOSITION defines the search to be performed on the composition of certain zone materials.

ZM1 is the zone material on which the search is performed. The concentrations of the nuclides labeled FUEL are varied uniformly to achieve the desired value of k_{eff} . The concentrations of the DILUENT nuclides, if present, are varied so as to maintain a constant FUEL-DILUENT volume.

1.002 is the desired value of k_{eff} .

Card 4

EDIT

indicates that the following list of edits is to be performed.

NEUTRONICS edits quantities pertaining to the reactor neutron balance.

ZONE edits quantities corresponding to each zone, such as nuclide masses, reaction rates, etc.

REACTOR edits parameters similar to the ZONE edit, except that they apply to the entire reactor.

Card 5

DEplete calls RAIM CONTROL which sets up the flux-depletion sequence.

0.0 is the initial time (days) for the depletion sequence.

8 is the number of major time periods in the depletion sequence.

50.0 is the length (days) of each major depletion period.

5 is the number of minor time steps during each major depletion period.

ZONE-MATERIAL initiates edit calculations pertaining to each zone material.

REACTOR calls the reactor edit.

Card 6

TEST indicates that specified tests are to be performed at the end of each major depletion period.

CONTROL indicates that a composition search is to be performed at the end of each depletion period.

ZM8 is the zone material on which the search is performed.

1.002 is the desired value of k_{eff} .

Card 7

IMINIMUM indicates that the default value of some isotope is to be checked.

TA82 is the isotope whose concentration is to be checked.

0.0 is the default value for the concentration of TA82.

If its concentration falls below this value, depletion is terminated.

ZM8 is the zone material which contains TA82.

Card 8

BMAXIMUM indicates that the calculated burnup for some zone material is to be compared with the corresponding default value.

33000.0 is the maximum burnup default value.

ZM1 is the zone material whose burnup is not to exceed the default value.

Card 9

EDIT indicates that certain edits are to be executed (see card 4).

2.4. REGA

REGA prepares a 30-group (or less) microscopic cross-section set for each block in the reactor. During the past quarter, the REGA primary overlay (Figure 2-3) was developed further to include program BGMCS (Figure 2-4) which prepares microscopic cross-section sets for RAIM. BGMCS is currently in the debugging stage. STRIP and UNRES are approximately 99% complete. The overlay structure for REGA is illustrated in Figure 2-2. It is anticipated that the REGA programs in overlay form will be completed and functioning as a complete unit by January 1, 1969.

Figure 2-2. REGA Overlay Structure

Figure 2-3. REGA Flowchart

Figure 2-4. BGMCS Flowchart

2.5. RAIM

The RAIM program is made up of the primary overlay RAIM CONTROL and six secondary overlays. Each secondary overlay is called from RAIM CONTROL according to a specified sequence determined by the appropriate operational directives. The calculations that each of the secondary overlays performs are discussed below.

2.5.1. MACRO

Overlay MACRO reads microscopic cross sections for each nuclide from the REGA library tape and calculates the appropriate macroscopic cross sections for each energy group and each zone. The microscopic cross sections for nuclide l and energy group i , which are available on the REGA library tape, are as follows:

1. $\sigma_{c_i}^l$ - microscopic capture cross section.
2. $\sigma_{f_i}^l$ - microscopic fission cross section.
3. ν_i^l - average number of neutrons per fission.
4. $\sigma_{j \rightarrow i}^l$ - microscopic scattering cross section matrix.
5. $\sigma_{tr_i}^l$ - microscopic transport cross section.
6. $\sigma_{2n_i}^l$ - microscopic $(n, 2n)$ cross section.
7. δ_i^l - correction for microscopic removal cross section.

The transfer matrix includes the elastic, inelastic, and $(n, 2n)$ scattering terms

$$\sigma_{j \rightarrow i} = \sigma_{j \rightarrow i}^{\text{elastic}} + 2 \sigma_{2n_j \rightarrow i} + \sigma_{j \rightarrow i}^{\text{inelastic}}.$$

The removal correction cross section includes the (n, p) and (n, α) cross sections minus the total $(n, 2n)$ cross section for each group.

MACRO also writes the microscopic capture, fission, $(n, 2n)$ and absorption cross sections on a disk file for use in the REDEP program. The microscopic absorption cross section is given by

$$\sigma_{a_i}^{\ell} = \sigma_{c_i}^{\ell} + \sigma_{f_i}^{\ell} + \delta_i^{\ell} + \sigma_{2n_i}^{\ell}$$

The following macroscopic cross sections are computed by MACRO for each energy group i and zone M :

1. $\Sigma_{c_i}^M$ - macroscopic capture cross section.
2. $\Sigma_{f_i}^M$ - macroscopic fission cross section.
3. $\nu_i \Sigma_{f_i}^M$ - macroscopic ν -fission cross section.
4. $\Sigma_{j \rightarrow i}^M$ - macroscopic scattering cross section matrix.
5. $\Sigma_{tr_i}^M$ - macroscopic transport cross section.
6. $D_i^M = 1/3 \Sigma_{tr_i}^M$ - diffusion coefficient.
7. $\Sigma_{2n_i}^M$ - macroscopic $(n, 2n)$ cross section.
8. $\Delta_i^M = \Sigma_{\delta_i}^M$ - macroscopic removal correction cross section.
9. $\Sigma_{a_i}^M$ - macroscopic absorption cross section.
10. $\Sigma_{T_i}^M$ - macroscopic total (removal) cross section, where

$$\Sigma_{T_i}^M = D_i^M (B_i^M)^2 + \Sigma_{c_i}^M + \Sigma_{f_i}^M + \Delta_i^M + \sum_{j>i} \Sigma_{i \rightarrow j}^M$$

and $(B_i^M)^2$ = buckling in the transverse direction.

The macroscopic cross sections are computed according to

$$\Sigma_{X_i}^M = \sum_{\ell \in M} \sigma_{X_i}^{\ell} N_M^{\ell}$$

where N_M^{ℓ} = concentration of nuclide ℓ in zone M .

2.5.2. CONS

Overlay CONS uses the zone- and group-dependent macroscopic cross sections calculated in MACRO to compute the coefficients necessary for program FLUX. This program also calculates the inner and outer boundary extrapolation lengths if the appropriate options are specified.

2.5.3. FLUX

Overlay FLUX solves the following coupled equations for the eigenvalue, λ , and the group fluxes, $\phi_i(r)$:

$$-D_i \nabla^2 \phi_i(\bar{r}) + \Sigma_{T_i} \phi_i(\bar{r}) = 1/\lambda \chi_i S(\bar{r}) + \sum_{j=q}^{i-1} \Sigma_{j \rightarrow i} \phi_j(\bar{r})$$

where

$$S(\bar{r}) = \sum_{j=1}^{NOG} \nu_j \Sigma_{f_j} \phi_j(\bar{r})$$

NOG = number of energy groups

NDS = number of downscattering groups

$$q = \text{MAX}(1, i - \text{NDS})$$

FLUX returns program control to RAIM CONTROL with the converged eigenvalue and group fluxes.

2.5.4. CRIT

The various criticality searches are performed by overlay CRIT, which adjusts appropriate parameters according to the type of search. Convergence of the search parameters is checked in RAIM CONTROL after each criticality iteration. If convergence has not been achieved, new fluxes are computed and CRIT recalculates the search parameters.

The criticality searches available in the FARED Code are as follows:

1. COMPOSITION — the concentrations of the FUEL nuclides for specified zone materials are uniformly varied to achieve the desired value of k_{eff} .

If DILUENT nuclides are specified in any zone material, the DILUENT nuclide concentrations are also varied to maintain a constant FUEL-DILUENT volume within each zone material.

2. VDIMENSION — the widths of specified zones are uniformly varied to achieve the desired value of k_{eff} . The outer dimension of the reactor will vary accordingly.

3. FDIMENSION — similar to the search above except that the outer dimension of the reactor is fixed. The widths of zones adjacent to the search zones are varied to maintain the fixed outer dimension.

4. BUCKLING — values of the group-dependent transverse buckling are varied uniformly in specified zones to obtain the desired value of k_{eff} .

2.5.5. REDEP

Program REDEP performs the depletion calculation for all nuclides during one major depletion period. This overlay is called from RAIM CONTROL in accordance with a depletion sequence defined by a DEplete directive.

The general nuclide depletion equation can be written as

$$\frac{dN^{\ell}(t)}{dt} = Q^{\ell}(t) - A^{\ell}(t)N^{\ell}(t)$$

where

$N^{\ell}(t)$ = concentration of nuclide ℓ at time t

$Q^{\ell}(t)$ = production rate of nuclide ℓ at time t

$A^{\ell}(t)N^{\ell}(t)$ = destruction rate of nuclide ℓ at time t

The coefficient $A^{\ell}(t)$ is given by

$$A^{\ell}(t) = \lambda_{\ell} + \sum_{j=1}^{NOG} \sigma_{a_j}^{\ell} \bar{\phi}_j(t)$$

where

λ_{ℓ} = decay constant for nuclide ℓ

$$\bar{\phi}_j(t) = \frac{1}{V} \int_V \phi_j(r, t) dV$$

The integration is performed over the volume, V , for the zone in which nuclide ℓ occurs.

The production rate, $Q^\ell(t)$, is given in terms of several individual production terms, $q_i^\ell(t)$:

$$Q^\ell(t) = \sum_i q_i^\ell(t)$$

There are four different methods for producing nuclide ℓ , any of which may apply for a given nuclide:

1. Nuclide ℓ is a fission product of any number of fissionable nuclides M , $m = 1, 2, \dots, M$.

$$q_1^\ell(t) = \sum_{j=1}^{\text{NOG}} \bar{\phi}_j(t) \sum_{m=1}^M \gamma_m^\ell \sigma_{fj}^m N^m(t)$$

where γ_m^ℓ = fractional yield of nuclide ℓ from the fission of nuclide m .

2. Nuclide ℓ is formed by a neutron capture in nuclide m :

$$q_2^\ell(t) = \sum_{j=1}^{\text{NOG}} \bar{\phi}_j(t) \sigma_{cj}^m N^m(t)$$

3. Nuclide ℓ is formed by the radioactive decay of nuclide m :

$$q_3^\ell(t) = \lambda_m N^m(t)$$

4. Nuclide ℓ is formed by an $(n, 2n)$ reaction of nuclide m :

$$q_4^\ell(t) = \sum_{j=1}^{\text{NOG}} \bar{\phi}_j(t) \sigma_{2nj}^m N^m(t)$$

The appropriate production terms are determined according to a decay chain matrix on the RETAP library tape. The average

fluxes, $\bar{\phi}_j(t_o)$, and nuclide concentrations, $N^l(t_o)$, are known at the beginning of each major time step of length Δt . The major depletion period is divided into N minor time steps of length δt , where

$$\delta t = \Delta t / N.$$

In order to determine the nuclide concentrations $N^l(t_o + n\delta t)$ at the end of the n^{th} minor time step, the following assumptions are made pertaining to the behavior of various parameters during the time interval $t \in [t_o + (n-1)\delta t, t_o + n\delta t]$:

1. $\bar{\phi}_j(t) = \bar{\phi}_j(t_o)$
2. $A^l(t) = A^l(t_o)$
3. $Q^l(t) = \frac{1}{2} \left\{ Q^l(t_o + n\delta t) + Q^l[t_o + (n-1)\delta t] \right\}$
4. $N^l(t) = \frac{1}{2} \left\{ N^l(t_o + n\delta t) + N^l[t_o + (n-1)\delta t] \right\}$
5. $\frac{dN^l(t)}{dt} = \frac{1}{\delta t} \left\{ N^l(t_o + n\delta t) - N^l[t_o + (n-1)\delta t] \right\}$

The solution of the depletion equation for each minor time step, $t = t_o + n\delta t$, is given by

$$N^l(t_o + n\delta t) = \frac{[2 - A^l(t_o)\delta t]N^l[t_o + (n-1)\delta t] + \delta t \left\{ Q^l(t_o + n\delta t) + Q^l[t_o + (n-1)\delta t] \right\}}{2 + A^l(t_o)\delta t}$$

After the last minor time step, the nuclide concentrations corresponding to the end of the major depletion period are stored in COMMON, and the fluxes are recomputed.

2.5.6. EDIT

Overlay EDIT is composed of a number of routines, each of which performs a group of related edit calculations. Each edit routine

is called by an appropriate directive. Although not all edits have been formulated in detail, general calculations have been decided. As an example, a ZONE edit will compute the following quantities for each reactor zone:

1. Masses of all nuclides.
2. Capture and fission power distributions.
3. Capture and fission power.
4. Peak-to-average power.
5. Median fission, absorption, capture, and flux energies.
6. Conversion and breeding ratios.

3. BURNUP STUDIES

3.1. Summary of Computational Procedure

Depletion calculations have been completed for both the 2000- and the 8000-liter cores using the three combinations of cross-section data, i.e., a reference library, a second set with reference data except that fission product capture cross sections are increased 50% at all energies, and a third set employing reference data except for a 50% increase in the ^{239}Pu capture cross sections at all neutron energies.

In all cases the beginning-of-cycle feed enrichments were adjusted by zones to obtain the desired initial k_{eff} and a reasonably flat power distribution. The initial k_{eff} for a given fuel cycle is that resulting in a maximum heavy atom burnup of 10% in the core. For the first cycle in a given case, the maximum local heavy atom burnup experienced in the core is 5%. Half the volume of the core and the axial blanket fuel is removed at the end of each fuel cycle. Therefore, for each fuel cycle following the first, two levels of fuel exposure are present in the core and the axial blanket. Half the volume of the radial blanket fuel is removed on alternate fuel cycles. Therefore, two levels of fuel exposure are present in the radial blanket following cycle 2 for a given case. Within the limits of practicality, the refueling scheme for the radial blanket is designed to result in maximum utilization without exceeding the limit of 10% maximum localized heavy atom burnup. Of course, the axial blanket must be cycled with the core in a conventional cylindrical design regardless of burnup considerations.

The generalized refueling scheme used is as follows:

Generalized Refueling Scheme
(Levels of Fuel Exposure at BOC)

	Cycle					
	1	2	3	4	5	6
Core	0 + 0	0 + 1	0 + 1	0 + 1	0 + 1	0 + 1
Axial blanket	0 + 0	0 + 1	0 + 1	0 + 1	0 + 1	0 + 1
Radial blanket	0 + 0	1 + 1	0 + 2	1 + 3	0 + 2	1 + 3

Note: 0 = fresh fuel
 1 = fuel irradiated for 1 complete cycle
 2 = fuel irradiated for 2 complete cycles

As has been explained previously, equilibrium takes the form of essentially identical alternate repeating cycles (i.e., cycles 3, 5, 7 . . . and 4, 6, 8 . . .) instead of successive repeating cycles. This is due to the radial blanket management procedure. In all cases the fourth fuel cycle is designated as the equilibrium cycle.

The abbreviated notation used in this section is as follows:

Designation	Item
Small	2000-liter core
Large	8000-liter core
Ref	Reference cross section set for either 2000- or 8000-liter core
FF	Reference cross section set with fission product capture cross sections increased 50% at all neutron energies
Pu	Reference cross section set with ^{239}Pu capture cross sections increased 50% at all neutron energies
BOC	Beginning of a fuel cycle
EOC	End of a fuel cycle
EC	Equilibrium cycle

3.2. Results

Tables 3-1 through 3-6 show total breeding ratios (BOC and EOC) for each fuel cycle in each case. For the small core, the use of the FF cross section set resulted in a reduction of approximately 3% in the total breeding ratio at EC-BOC. At EC-EOC the reduction in total breeding ratio was approximately 0.4%. Using the Pu set, the reduction in total breeding ratio for the 2000-liter core is approximately 14% at EC-BOC, and approximately 11.5% at EC-EOC.

For the 8000-liter core, the reduction in total breeding ratio at EC-BOC resulting from using the FF set is approximately 1.5%. At EC-EOC the reduction is about 1%. Using the Pu set, the total breeding ratio is reduced about 12.5% at EC-BOC and about 9% at EC-EOC. Thus, as expected, the effect on breeding ratio is much more pronounced using the Pu set.

Tables 3-7 through 3-12 present power peaking factors for each cycle of each case at both BOC and EOC. Also, the ratio of these peaking factors in the two core zones is given for ease of comparison. Based on these tables, the introduction of the FF or Pu sets does not seem to appreciably affect the power peaking, all other conditions remaining the same.

Tables 3-13 through 3-18 give feed, BOC average, EOC average, and discharge enrichments for each core zone and average for the core for each fuel cycle in each case. For the 2000-liter core, the FF set results in an increase in average core enrichment of about 3.5% at EC-BOC and about 3% at EC-EOC. Using the Pu set, the corresponding increases in average core enrichments are about 8% at EC-BOC and 5% at EC-EOC. For the 2000-liter core, the increase in average core enrichment at EC-BOC is about 2% when using the FF set. At EC-EOC, the increase is about 1%. Employing the Pu set results in increases of about 5% at EC-BOC and about 1.5% EC-EOC. Thus, the required enrichment is increased more when using the Pu set than the FF set.

Tables 3-19 through 3-68 show BOC and EOC total mass balances and EOC discharge mass balances by isotope and by core and blankets for each cycle of each case.

Table 3-69 shows the average core discharge Pu isotopic mixes for all cases. The feed Pu-mix in all cases was 76% ^{239}Pu , 19% ^{240}Pu ,

3.5% ^{241}Pu , and 1.5% ^{242}Pu . Comparing the cases using the ref and Pu cross section sets, as would be expected, there is a reduction in the ^{239}Pu fraction and a gain in the ^{240}Pu fraction due to the increased ^{239}Pu captures. Very small changes are seen when comparing the cases using the ref and FF cross-section sets.

Table 3-1. Total Breeding Ratios
(Small Core, Ref Library)

<u>Cycle</u>	<u>BOC</u>	<u>EOC</u>
1	1.4200	1.4001
2	1.3684	1.3607
3	1.3628	1.3562
4	1.3630	1.3540
5	1.3795	1.3680

Table 3-2. Total Breeding Ratios
(Small Core, Ref Library)

<u>Cycle</u>	<u>BOC</u>	<u>EOC</u>
1	1.3975	1.3858
2	1.3304	1.3324
3	1.3481	1.3462
4	1.3259	1.3481

Table 3-3. Total Breeding Ratios
(Small Core, Pu Library)

<u>Cycle</u>	<u>BOC</u>	<u>EOC</u>
1	1.2099	1.2421
2	1.1890	1.2213
3	1.1839	1.2173
4	1.1683	1.2001

Table 3-4. Total Breeding Ratios
(Large Core, Ref Library)

<u>Cycle</u>	<u>BOC</u>	<u>EOC</u>
1	1.4554	1.3463
2	1.3923	1.3055
3	1.3916	1.3059
4	1.3792	1.2974

Table 3-5. Total Breeding Ratios
(Large Core, FF Library)

<u>Cycle</u>	<u>BOC</u>	<u>EOC</u>
1	1.4300	1.3324
2	1.3695	1.2933
3	1.3732	1.2962
4	1.3573	1.2852

Table 3-6. Total Breeding Ratios
(Large Core, Pu Library)

<u>Cycle</u>	<u>BOC</u>	<u>EOC</u>
1	1.2272	1.1981
2	1.2139	1.1868
3	1.2078	1.1829
4	1.2051	1.1792

Table 3-7. Power Peaking Factors
(Small Core, Ref Library)

	<u>BOC</u>	<u>EOC</u>
<u>Cycle 1</u>		
Core zone 1	1.2876	1.3637
Core zone 2	1.2781	1.2194
$(PF)_1/(PF)_2$	1.0074	1.1183
<u>Cycle 2</u>		
Core zone 1	1.3196	1.3752
Core zone 2	1.2454	1.1992
$(PF)_1/(PF)_2$	1.0590	1.1468
<u>Cycle 3</u>		
Core zone 1	1.3010	1.3597
Core zone 2	1.2547	1.2071
$(PF)_1/(PF)_2$	1.0369	1.1264
<u>Cycle 4</u>		
Core zone 1	1.3192	1.3714
Core zone 2	1.2367	1.1920
$(PF)_1/(PF)_2$	1.0667	1.1505
<u>Cycle 5</u>		
Core zone 1	1.2837	1.3493
Core zone 2	1.2623	1.2113
$(PF)_1/(PF)_2$	1.0170	1.1140

Table 3-8. Power Peaking Factors
(Small Core, FF Library)

	<u>BOC</u>	<u>EOC</u>
<u>Cycle 1</u>		
Core zone 1	1.2862	1.3521
Core zone 2	1.2772	1.2228
$(PF)_1/(PF)_2$	1.0071	1.1057
<u>Cycle 2</u>		
Core zone 1	1.2430	1.2953
Core zone 2	1.2886	1.2327
$(PF)_1/(PF)_2$	0.96464	1.0507
<u>Cycle 3</u>		
Core zone 1	1.2501	1.3047
Core zone 2	1.2859	1.2288
$(PF)_1/(PF)_2$	0.97216	1.0618
<u>Cycle 4</u>		
Core zone 1	1.2219	1.2787
Core zone 2	1.2891	1.2317
$(PF)_1/(PF)_2$	0.94788	1.0381

Table 3-9. Power Peaking Factors
(Small Core, Pu Library)

	<u>BOC</u>	<u>EOC</u>
<u>Cycle 1</u>		
Core zone 1	1.2847	1.3302
Core zone 2	1.2775	1.2362
$(PF)_1/(PF)_2$	1.0057	1.0760
<u>Cycle 2</u>		
Core zone 1	1.2865	1.2923
Core zone 2	1.2522	1.2389
$(PF)_1/(PF)_2$	0.97334	1.0431
<u>Cycle 3</u>		
Core zone 1	1.2568	1.2956
Core zone 2	1.2858	1.2388
$(PF)_1/(PF)_2$	0.97744	1.0459
<u>Cycle 4</u>		
Core zone 1	1.2344	1.2753
Core zone 2	1.2871	1.2396
$(PF)_1/(PF)_2$	0.95906	1.0288

Table 3-10. Power Peaking Factors
(Large Core, Ref Library)

	<u>BOC</u>	<u>EOC</u>
<u>Cycle 1</u>		
Core zone 1	1.0446	1.3248
Core zone 2	1.3612	1.2319
$(PF)_1/(PF)_2$	0.76737	1.0754
<u>Cycle 2</u>		
Core zone 1	1.1695	1.3904
Core zone 2	1.2988	1.1956
$(PF)_1/(PF)_2$	0.90046	1.1629
<u>Cycle 3</u>		
Core zone 1	1.1246	1.3540
Core zone 2	1.3160	1.2088
$(PF)_1/(PF)_2$	0.85459	1.1201
<u>Cycle 4</u>		
Core zone 1	1.0913	1.3196
Core zone 2	1.3168	1.2109
$(PF)_1/(PF)_2$	0.82878	1.0898

Table 3-11. Power Peaking Factors
(Large Core, FF Library)

	<u>BOC</u>	<u>EOC</u>
<u>Cycle 1</u>		
Core zone 1	1.0447	1.3002
Core zone 2	1.3614	1.2383
$(PF)_1/(PF)_2$	0.76736	1.0500
<u>Cycle 2</u>		
Core zone 1	1.1561	1.3547
Core zone 2	1.3028	1.2045
$(PF)_1/(PF)_2$	0.88741	1.1247
<u>Cycle 3</u>		
Core zone 1	1.1191	1.3269
Core zone 2	1.3168	1.2145
$(PF)_1/(PF)_2$	0.84987	1.0925
<u>Cycle 4</u>		
Core zone 1	1.0856	1.2919
Core zone 2	1.3182	1.2174
$(PF)_1/(PF)_2$	0.82352	1.0612

Table 3-12. Power Peaking Factors
(Large Core, Pu Library)

	<u>BOC</u>	<u>EOC</u>
<u>Cycle 1</u>		
Core zone 1	1.0358	1.2473
Core zone 2	1.3591	1.2611
$(PF)_1/(PF)_2$	0.76210	0.98909
<u>Cycle 2</u>		
Core zone 1	1.1331	1.3130
Core zone 2	1.3130	1.2231
$(PF)_1/(PF)_2$	0.86302	1.0735
<u>Cycle 3</u>		
Core zone 1	1.1084	1.2903
Core zone 2	1.3229	1.2317
$(PF)_1/(PF)_2$	0.83783	1.0476
<u>Cycle 4</u>		
Core zone 1	1.1054	1.2856
Core zone 2	1.3137	1.2243
$(PF)_1/(PF)_2$	0.84142	1.0501

Table 3-13. Enrichments^(a)
(Small Core, Ref Library)

	<u>Feed</u>	<u>BOC</u>	<u>EOC</u>	<u>Discharge</u>
<u>Cycle 1</u>				
Core zone 1	0.11564	0.11564	0.12063	0.12063
Core zone 2	0.19658	0.19658	0.18653	0.18653
Core average	0.15620	0.15620	0.15368	0.15368
<u>Cycle 2</u>				
Core zone 1	0.12050	0.12056	0.12414	0.12424
Core zone 2	0.20238	0.19461	0.18516	0.17832
Core average	0.16154	0.15768	0.15477	0.15141
<u>Cycle 3</u>				
Core zone 1	0.11705	0.12048	0.12406	0.12679
Core zone 2	0.20246	0.19721	0.18739	0.18279
Core average	0.15986	0.15895	0.15584	0.15492
<u>Cycle 4</u>				
Core zone 1	0.11505	0.12069	0.12431	0.12897
Core zone 2	0.20008	0.19175	0.18278	0.17523
Core average	0.15766	0.15634	0.15368	0.15227
<u>Cycle 5</u>				
Core zone 1	0.11705	0.11850	0.12263	0.12380
Core zone 2	0.20246	0.19625	0.18649	0.18104
Core average	0.15986	0.15747	0.15466	0.20288

(a) In Tables 3-13 through 3-18, enrichment = $\frac{\text{mass } ({}^{239}\text{Pu} + {}^{241}\text{Pu})}{\text{mass } (\text{Pu} + \text{U})}$
including ${}^{23}\text{Np}$ correction.

Table 3-14. Enrichments
(Small Core, FF Library)

	<u>Feed</u>	<u>BOC</u>	<u>EOC</u>	<u>Discharge</u>
<u>Cycle 1</u>				
Core zone 1	0.11736	0.11736	0.12179	0.12179
Core zone 2	0.19951	0.19951	0.18911	0.18911
Core average	0.15853	0.15853	0.15555	0.15555
<u>Cycle 2</u>				
Core zone 1	0.12085	0.12131	0.12450	0.12491
Core zone 2	0.22341	0.20660	0.19554	0.18058
Core average	0.17228	0.16408	0.16012	0.15283
<u>Cycle 3</u>				
Core zone 1	0.11607	0.12001	0.12357	0.12671
Core zone 2	0.19828	0.20403	0.19325	0.19845
Core average	0.15727	0.16210	0.15847	0.16263
<u>Cycle 4</u>				
Core zone 1	0.11818	0.11934	0.12300	0.12396
Core zone 2	0.21820	0.20352	0.19296	0.17990
Core average	0.16833	0.16154	0.15805	0.15202

Table 3-15. Enrichments
(Small Core, Pu Library)

	<u>Feed</u>	<u>BOC</u>	<u>EOC</u>	<u>Discharge</u>
<u>Cycle 1</u>				
Core zone 1	0.12492	0.12492	0.12417	0.12417
Core zone 2	0.21235	0.21235	0.19755	0.19755
Core average	0.16874	0.16874	0.16096	0.16096
<u>Cycle 2</u>				
Core zone 1	0.12625	0.12523	0.12379	0.12450
Core zone 2	0.22816	0.21316	0.18527	0.19848
Core average	0.17735	0.16932	0.15464	0.16159
<u>Cycle 3</u>				
Core zone 1	0.12634	0.12577	0.12453	0.12490
Core zone 2	0.21688	0.21411	0.19698	0.19935
Core average	0.17172	0.17004	0.16081	0.16220
<u>Cycle 4</u>				
Core zone 1	0.12483	0.12503	0.12437	0.12461
Core zone 2	0.22407	0.21307	0.19863	0.18893
Core average	0.17458	0.16916	0.16158	0.15686

Table 3-16. Enrichments
(Large Core, Ref Library)

	<u>Feed</u>	<u>BOC</u>	<u>EOC</u>	<u>Discharge</u>
<u>Cycle 1</u>				
Core zone 1	0.09229	0.09229	0.10485	0.10485
Core zone 2	0.15689	0.15689	0.15273	0.15273
Core average	0.12465	0.12465	0.12883	0.12883
<u>Cycle 2</u>				
Core zone 1	0.09229	0.09846	0.10908	0.11371
Core zone 2	0.15689	0.15485	0.15126	0.14955
Core average	0.12465	0.12671	0.13024	0.13171
<u>Cycle 3</u>				
Core zone 1	0.09127	0.09783	0.10854	0.11348
Core zone 2	0.16007	0.15677	0.15281	0.15003
Core average	0.12574	0.12737	0.13075	0.13184
<u>Cycle 4</u>				
Core zone 1	0.09142	0.09750	0.10808	0.11269
Core zone 2	0.15718	0.15635	0.15248	0.15182
Core average	0.12436	0.12698	0.13033	0.13232

Table 3-17. Enrichments
(Large Core, FF Library)

	<u>Feed</u>	<u>BOC</u>	<u>EOC</u>	<u>Discharge</u>
<u>Cycle 1</u>				
Core zone 1	0.09381	0.09381	0.10571	0.10571
Core zone 2	0.15948	0.15948	0.15487	0.15487
Core average	0.12671	0.12671	0.13033	0.13033
<u>Cycle 2</u>				
Core zone 1	0.09438	0.09995	0.10989	0.11411
Core zone 2	0.16044	0.15770	0.15362	0.15130
Core average	0.12747	0.12888	0.13182	0.13278
<u>Cycle 3</u>				
Core zone 1	0.09268	0.09914	0.10927	0.11417
Core zone 2	0.16175	0.15885	0.15453	0.15208
Core average	0.12728	0.12906	0.13197	0.13320
<u>Cycle 4</u>				
Core zone 1	0.09368	0.09902	0.10896	0.11305
Core zone 2	0.16073	0.15885	0.15454	0.15297
Core average	0.12726	0.12899	0.13180	0.13307

Table 3-18. Enrichments
(Large Core, Pu Library)

	<u>Feed</u>	<u>BOC</u>	<u>EOC</u>	<u>Discharge</u>
<u>Cycle 1</u>				
Core zone 1	0.10044	0.10044	0.10726	0.10726
Core zone 2	0.17074	0.17074	0.16158	0.16158
Core average	0.13566	0.13566	0.13446	0.13446
<u>Cycle 2</u>				
Core zone 1	0.09817	0.10264	0.10872	0.11208
Core zone 2	0.16711	0.16439	0.15652	0.15428
Core average	0.13271	0.13357	0.13268	0.13324
<u>Cycle 3</u>				
Core zone 1	0.10011	0.10275	0.10875	0.11076
Core zone 2	0.17370	0.16632	0.15809	0.15189
Core average	0.13698	0.13460	0.13348	0.13139
<u>Cycle 4</u>				
Core zone 1	0.09785	0.10225	0.10834	0.11167
Core zone 2	0.16332	0.16371	0.15598	0.15638
Core average	0.13065	0.13303	0.13221	0.13408

Table 3-19. Mass Balance, kg
(Small Core, Ref Library, Cycle 1)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
$^{239}\text{Pu}^{(a)}$	968.81	0.00	0.00	968.81
^{240}Pu	242.20	0.00	0.00	242.20
^{241}Pu	44.62	0.00	0.00	44.62
^{242}Pu	19.12	0.00	0.00	19.12
Total Pu	1274.75	0.00	0.00	1,274.75
^{238}U	5213.21	4287.79	18,495.27	27,996.27
Total (U + Pu)	6487.96	4287.79	18,495.27	29,271.02
<u>EOC</u>				
$^{239}\text{Pu}^{(a)}$	916.39	46.15	112.19	1,074.73
^{240}Pu	264.19	0.52	0.99	265.70
^{241}Pu	42.82	0.00	0.01	42.83
^{242}Pu	19.30	0.00	0.00	19.30
Total Pu	1242.70	46.67	113.19	1,402.56
^{238}U	4998.98	4236.98	18,374.18	27,610.14
Total (U + Pu)	6241.68	4283.65	18,487.37	29,012.70

(a) Includes ^{239}Np correction in Tables 3-19 through 3-68.

Table 3-20. Discharge Mass Balance, kg
(Small Core, Ref Library, Cycle 1)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
^{239}Pu	458.20	23.08	0.00	481.28
^{240}Pu	132.10	0.26	0.00	132.36
^{241}Pu	21.41	0.00	0.00	21.41
^{242}Pu	9.65	0.00	0.00	9.65
Total Pu	621.35	23.34	0.00	644.69
^{238}U	2499.49	2118.49	0.00	4,617.98
Total (U + Pu)	3120.84	2141.83	0.00	5,262.67

Table 3-21. Mass Balance, kg
(Small Core, Ref Library, Cycle 2)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	959.28	23.22	112.19	1,094.69
²⁴⁰ Pu	267.37	0.26	0.99	258.62
²⁴¹ Pu	44.49	0.00	0.01	44.50
²⁴² Pu	19.54	0.00	0.00	19.54
Total Pu	1280.68	23.48	113.19	1,417.35
²³⁸ U	5085.12	4262.39	18,374.18	27,721.69
Total (U + Pu)	6365.80	4285.87	18,487.37	29,139.04
<u>EOC</u>				
²³⁹ Pu	905.09	66.76	216.40	1,188.25
²⁴⁰ Pu	276.81	1.23	3.73	281.77
²⁴¹ Pu	43.32	0.02	0.06	43.40
²⁴² Pu	19.67	0.00	0.00	19.67
Total Pu	1244.89	68.01	220.19	1,533.09
²³⁸ U	4883.00	4211.93	18,252.84	27,347.77
Total (U + Pu)	6127.89	4279.94	18,473.03	28,880.86

Table 3-22. Discharge Mass Balance, kg
(Small Core, Ref Library, Cycle 2)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	433.91	43.79	108.20	585.90
²⁴⁰ Pu	140.71	0.98	1.87	143.56
²⁴¹ Pu	21.20	0.00	0.03	21.23
²⁴² Pu	9.70	0.00	0.00	9.70
Total Pu	605.52	44.77	110.10	760.39
²³⁸ U	2400.27	2093.44	9,126.42	13,620.13
Total (U + Pu)	3005.79	2138.21	9,236.52	14,380.52

Table 3-23. Mass Balance, kg
(Small Core, Ref Library, Cycle 3)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	967.02	22.97	108.20	1,098.19
²⁴⁰ Pu	260.07	0.25	1.86	262.18
²⁴¹ Pu	44.96	0.00	0.03	44.99
²⁴² Pu	19.76	0.00	0.00	19.76
Total Pu	1291.81	23.22	110.09	1,425.12
²³⁸ U	5074.95	4262.38	18,374.05	27,711.38
Total (U + Pu)	6366.76	4285.60	18,594.23	29,246.59
<u>EOC</u>				
²³⁹ Pu	911.31	66.46	212.68	1,190.45
²⁴⁰ Pu	279.41	1.21	4.46	285.08
²⁴¹ Pu	43.77	0.02	0.10	43.89
²⁴² Pu	19.88	0.00	0.00	19.88
Total Pu	1254.37	67.69	217.24	1,539.30
²³⁸ U	4874.09	4212.01	18,252.96	27,339.06
Total (U + Pu)	6128.46	4279.70	18,470.20	28,878.36

Table 3-24. Discharge Mass Balance, kg
(Small Core, Ref Library, Cycle 3)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	443.64	43.54	0.00	487.18
²⁴⁰ Pu	144.80	0.96	0.00	145.76
²⁴¹ Pu	21.88	0.02	0.00	21.90
²⁴² Pu	10.02	0.00	0.00	10.02
Total Pu	620.34	44.52	0.00	664.86
²³⁸ U	2384.60	2093.48	0.00	4,478.08
Total (U + Pu)	3004.94	2138.00	0.00	5,142.94

Table 3-25. Mass Balance, kg
(Small Core, Ref Library, Cycle 4)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	932.62	22.93	212.68	1,168.23
²⁴⁰ Pu	267.05	0.25	4.46	271.76
²⁴¹ Pu	44.40	0.00	0.10	44.50
²⁴² Pu	19.67	0.00	0.00	19.67
Total Pu	1263.74	23.18	217.24	1,504.16
²³⁸ U	4985.45	4262.42	18,252.96	27,500.83
Total (U + Pu)	6249.19	4285.60	18,470.20	29,004.99
<u>EOC</u>				
²³⁹ Pu	881.06	67.13	311.65	1,259.84
²⁴⁰ Pu	284.76	1.22	8.62	294.60
²⁴¹ Pu	43.69	0.02	0.23	43.94
²⁴² Pu	19.81	0.00	0.00	19.81
Total Pu	1229.32	68.37	320.50	1,618.19
²³⁸ U	4787.88	4211.01	18,129.71	27,128.60
Total (U + Pu)	6017.20	4279.38	18,450.21	28,746.79

Table 3-26. Discharge Mass Balance, kg
(Small Core, Ref Library, Cycle 4)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	418.40	43.84	201.79	664.03
²⁴⁰ Pu	151.81	0.96	6.77	159.54
²⁴¹ Pu	22.07	0.02	0.20	22.29
²⁴² Pu	10.07	0.00	0.00	10.07
Total Pu	602.35	44.82	208.76	855.93
²³⁸ U	2290.32	2092.99	9,005.60	13,388.91
Total (U + Pu)	2892.67	2137.81	9,214.36	14,244.84

Table 3-27. Mass Balance, kg
(Small Core, Ref Library, Cycle 5)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	958.50	23.29	109.86	1,091.65
²⁴⁰ Pu	256.92	0.25	1.85	259.02
²⁴¹ Pu	44.46	0.00	0.03	44.49
²⁴² Pu	19.52	0.00	0.00	19.52
Total Pu	1279.40	23.54	111.74	1,414.68
²³⁸ U	5089.78	4261.91	18,371.75	27,723.44
Total (U + Pu)	6369.18	4285.45	18,483.49	29,138.12
<u>EOC</u>				
²³⁹ Pu	904.93	67.21	215.43	1,187.57
²⁴⁰ Pu	276.42	1.23	4.50	282.15
²⁴¹ Pu	43.28	0.02	0.10	43.40
²⁴² Pu	19.65	0.00	0.00	19.65
Total Pu	1244.28	68.46	220.03	1,532.77
²³⁸ U	4886.86	4211.00	18,249.31	27,347.17
Total (U + Pu)	6131.14	4279.46	18,469.34	28,879.94

Table 3-28. Discharge Mass Balance, kg
(Small Core, Ref Library, Cycle 5)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	437.48	44.05	0.00	481.53
²⁴⁰ Pu	141.69	0.98	0.00	142.67
²⁴¹ Pu	21.39	0.02	0.00	21.41
²⁴² Pu	9.78	0.00	0.00	9.78
Total Pu	610.34	45.05	0.00	655.39
²³⁸ U	2398.09	2092.75	0.00	4,490.84
Total (U + Pu)	3008.43	2137.80	0.00	5,146.23

Table 3-29. Mass Balance, kg
(Small Core, FF Library, Cycle 1)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	983.38	0.00	0.00	983.38
²⁴⁰ Pu	245.85	0.00	0.00	245.85
²⁴¹ Pu	45.30	0.00	0.00	45.30
²⁴² Pu	19.41	0.00	0.00	19.41
Total Pu	1293.94	0.00	0.00	1,293.94
²³⁸ U	5194.88	4287.79	18,495.27	27,977.94
Total (U + Pu)	6488.82	4287.79	18,495.27	29,271.88
<u>EOC</u>				
²³⁹ Pu	927.57	45.72	111.21	1,084.50
²⁴⁰ Pu	267.56	0.51	0.96	269.03
²⁴¹ Pu	43.43	0.00	0.01	43.44
²⁴² Pu	19.57	0.00	0.00	19.57
Total Pu	1258.13	46.23	112.18	1,416.54
²³⁸ U	4984.36	4237.46	18,375.28	27,597.10
Total (U + Pu)	6242.49	4283.69	18,487.46	29,013.64

Table 3-30. Discharge Mass Balance, kg
(Small Core, FF Library, Cycle 1)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	463.78	22.86	0.00	486.64
²⁴⁰ Pu	133.78	0.26	0.00	134.04
²⁴¹ Pu	21.72	0.00	0.00	21.72
²⁴² Pu	9.79	0.00	0.00	9.79
Total Pu	629.07	23.12	0.00	652.19
²³⁸ U	2492.18	2118.73	0.00	4,610.91
Total (U + Pu)	3121.25	2141.85	0.00	5,263.10

Table 3-31. Mass Balance, kg
(Small Core, FF Library, Cycle 2)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	998.52	22.86	111.21	1,132.59
²⁴⁰ Pu	267.47	0.26	0.96	268.69
²⁴¹ Pu	46.35	0.00	0.01	46.36
²⁴² Pu	20.34	0.00	0.00	20.34
Total Pu	1332.68	23.12	112.18	1,467.98
²³⁸ U	5035.48	4262.63	18,375.28	27,673.39
Total (U + Pu)	6368.16	4285.75	18,487.46	29,141.37
<u>EOC</u>				
²³⁹ Pu	936.58	66.08	214.90	1,217.56
²⁴⁰ Pu	286.27	1.20	3.64	291.11
²⁴¹ Pu	44.99	0.02	0.06	45.07
²⁴² Pu	20.44	0.00	0.00	20.44
Total Pu	1288.28	67.30	218.60	1,574.18
²³⁸ U	4842.03	4212.53	18,254.59	27,309.15
Total (U + Pu)	6130.31	4279.83	18,473.19	28,883.33

Table 3-32. Discharge Mass Balance, kg
(Small Core, FF Library, Cycle 2)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	438.41	43.30	107.45	589.16
²⁴⁰ Pu	141.92	0.95	1.82	144.69
²⁴¹ Pu	21.42	0.02	0.03	21.47
²⁴² Pu	9.82	0.00	0.00	9.82
Total Pu	611.57	44.27	109.30	765.14
²³⁸ U	2396.71	2093.86	9,127.29	13,617.86
Total (U + Pu)	3008.28	2138.13	9,236.59	14,383.00

Table 3-33. Mass Balance, kg
(Small Core, FF Library, Cycle 3)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	985.92	22.78	107.45	1,116.15
²⁴⁰ Pu	266.29	0.25	1.82	268.36
²⁴¹ Pu	46.03	0.00	0.03	46.06
²⁴² Pu	20.25	0.00	0.00	20.25
Total Pu	1318.49	23.03	109.30	1,450.82
²³⁸ U	5047.72	4262.56	18,374.93	27,685.21
Total (U + Pu)	6366.21	4285.59	18,484.23	29,136.03
<u>EOC</u>				
²³⁹ Pu	926.43	66.33	212.30	1,205.06
²⁴⁰ Pu	285.05	1.20	4.40	290.65
²⁴¹ Pu	44.72	0.02	0.09	44.83
²⁴² Pu	20.35	0.00	0.00	20.35
Total Pu	1276.55	67.55	216.79	1,560.89
²³⁸ U	4851.54	4212.10	18,253.42	27,317.06
Total (U + Pu)	6128.09	4279.65	18,470.21	28,877.95

Table 3-34. Discharge Mass Balance, kg
(Small Core, FF Library, Cycle 3)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	469.99	43.39	0.00	513.38
²⁴⁰ Pu	152.97	0.95	0.00	153.92
²⁴¹ Pu	23.22	0.02	0.00	23.24
²⁴² Pu	10.65	0.00	0.00	10.65
Total Pu	656.83	44.36	0.00	701.19
²³⁸ U	2350.19	2093.62	0.00	4,443.81
Total (U + Pu)	3007.02	2137.98	0.00	5,145.00

Table 3-35. Mass Balance, kg
(Small Core, FF Library, Cycle 4)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	983.81	22.94	212.30	1,219.05
²⁴⁰ Pu	262.68	0.25	4.40	267.33
²⁴¹ Pu	45.56	0.00	0.09	45.65
²⁴² Pu	20.00	0.00	0.00	20.00
Total Pu	1312.05	23.19	216.79	1,552.03
²³⁸ U	5060.21	4262.38	18,253.41	27,576.00
Total (U + Pu)	6372.26	4285.57	18,470.20	29,128.03
<u>EOC</u>				
²³⁹ Pu	926.21	66.53	310.24	1,302.98
²⁴⁰ Pu	281.26	1.15	8.46	290.87
²⁴¹ Pu	44.24	0.02	0.22	44.48
²⁴² Pu	20.10	0.00	0.01	20.11
Total Pu	1271.81	67.70	318.93	1,658.44
²³⁸ U	4868.37	4211.67	18,131.49	27,211.53
Total (U + Pu)	6140.18	4279.37	18,450.42	28,869.97

Table 3-36. Discharge Mass Balance, kg
(Small Core, FF Library, Cycle 4)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	437.14	43.56	200.82	681.52
²⁴⁰ Pu	140.25	0.94	6.64	147.83
²⁴¹ Pu	21.21	0.02	0.19	21.42
²⁴² Pu	9.72	0.00	0.00	9.72
Total Pu	608.32	44.52	207.65	860.49
²³⁸ U	2406.76	2093.31	9,006.90	13,506.97
Total (U + Pu)	3015.08	2137.83	9,214.55	14,367.46

Table 3-37. Mass Balance, kg
(Small Core, Pu Library, Cycle 1)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	1047.330	0.000	0.000	1,047.330
²⁴⁰ Pu	261.834	0.000	0.000	261.834
²⁴¹ Pu	48.240	0.000	0.000	48.240
²⁴² Pu	20.670	0.000	0.000	20.670
Total Pu	1378.074	0.000	0.000	1,378.074
²³⁸ U	5114.458	4287.793	18,495.268	27,897.519
Total (U + Pu)	6492.532	4287.793	18,495.268	29,275.593
<u>EOC</u>				
²³⁹ Pu	959.066	43.840	107.144	1,110.050
²⁴⁰ Pu	302.024	0.692	1.318	304.034
²⁴¹ Pu	46.390	0.008	0.011	46.409
²⁴² Pu	20.762	0.000	0.000	20.762
Total Pu	1328.242	44.540	108.473	1,481.255
²³⁸ U	4918.204	4239.316	18,379.260	27,536.780
Total (U + Pu)	6246.446	4283.856	18,487.733	29,018.035

Table 3-38. Discharge Mass Balance, kg
(Small Core, Pu Library, Cycle 1)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	479.533	21.920	0.000	501.453
²⁴⁰ Pu	151.012	0.346	0.000	151.358
²⁴¹ Pu	23.195	0.004	0.000	23.199
²⁴² Pu	10.381	0.000	0.000	10.381
Total Pu	664.121	22.270	0.000	686.391
²³⁸ U	2459.102	2119.658	0.000	4,578.760
Total (U + Pu)	3123.223	2141.928	0.000	5,265.151

Table 3-43. Mass Balance, kg
(Small Core, Pu Library, Cycle 4)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	1029.398	22.029	204.525	1,255.952
²⁴⁰ Pu	288.456	0.338	6.030	294.824
²⁴¹ Pu	48.543	0.003	0.120	48.666
²⁴² Pu	21.255	0.000	0.002	21.257
Total Pu	1387.652	22.370	210.677	1,620.699
²³⁸ U	4984.679	4263.293	18,260.706	27,508.678
Total (U + Pu)	6372.331	4285.663	18,471.383	29,129.377
<u>EOC</u>				
²³⁹ Pu	944.417	63.726	297.957	1,306.100
²⁴⁰ Pu	323.513	1.609	11.544	336.666
²⁴¹ Pu	47.553	0.023	0.287	47.863
²⁴² Pu	21.312	0.000	0.006	21.318
Total Pu	1336.795	65.358	309.794	1,711.947
²³⁸ U	4802.465	4214.427	18,143.018	27,159.910
Total (U + Pu)	6139.260	4279.785	18,452.812	28,871.857

Table 3-44. Discharge Mass Balance, kg
(Small Core, Pu Library, Cycle 4)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	448.975	41.704	192.840	683.519
²⁴⁰ Pu	168.437	1.279	9.071	178.787
²⁴¹ Pu	23.572	0.020	0.251	23.843
²⁴² Pu	10.577	0.000	0.006	10.583
Total Pu	651.561	43.003	202.168	896.732
²³⁸ U	2361.042	2095.132	9,014.207	13,470.381
Total (U + Pu)	3012.603	2138.135	9,216.375	14,367.113

Table 3-45. Mass Balance, kg
(Large Core, Ref Library, Cycle 1)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	3087.07	0.00	0.00	3,087.07
²⁴⁰ Pu	771.77	0.00	0.00	771.77
²⁴¹ Pu	142.19	0.00	0.00	142.19
²⁴² Pu	60.93	0.00	0.00	60.93
Total Pu	4,061.96	0.00	0.00	4,061.96
²³⁸ U	<u>21,844.02</u>	<u>17,151.24</u>	<u>30,733.28</u>	<u>69,728.54</u>
Total (U + Pu)	25,905.98	17,151.24	30,733.28	73,790.50
<u>EOC</u>				
²³⁹ Pu	3,085.43	141.63	225.36	3,452.42
²⁴⁰ Pu	864.58	1.46	2.49	868.53
²⁴¹ Pu	138.86	0.01	0.02	138.89
²⁴² Pu	62.09	0.00	0.00	62.09
Total Pu	4,150.96	143.10	227.87	4,521.93
²³⁸ U	<u>20,875.73</u>	<u>16,997.75</u>	<u>30,487.76</u>	<u>68,361.24</u>
Total (U + Pu)	25,026.69	17,140.85	30,715.63	72,883.17

Table 3-46. Discharge Mass Balance, kg
(Large Core, Ref Library, Cycle 1)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	1,542.72	70.82	0.00	1,613.54
²⁴⁰ Pu	432.29	0.73	0.00	433.02
²⁴¹ Pu	69.43	0.01	0.00	69.44
²⁴² Pu	31.05	0.00	0.00	31.05
Total Pu	2,075.49	71.56	0.00	2,147.05
²³⁸ U	<u>10,437.87</u>	<u>8498.88</u>	<u>0.00</u>	<u>18,936.75</u>
Total (U + Pu)	12,513.36	8570.44	0.00	21,083.80

Table 3-47. Mass Balance, kg
(Large Core, Ref Library, Cycle 2)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	3,086.25	70.82	225.36	3,382.43
²⁴⁰ Pu	818.18	0.73	2.49	821.40
²⁴¹ Pu	140.52	0.01	0.02	140.55
²⁴² Pu	61.51	0.00	0.00	61.51
Total Pu	4,106.46	71.56	227.87	4,405.89
²³⁸ U	21,359.88	17,074.50	30,487.76	68,922.14
Total (U + Pu)	25,466.34	17,146.06	30,715.63	73,328.03
<u>EOC</u>				
²³⁹ Pu	3,065.24	205.11	427.14	3,697.49
²⁴⁰ Pu	903.70	3.40	9.15	916.25
²⁴¹ Pu	139.71	0.06	0.17	139.94
²⁴² Pu	62.55	0.00	0.00	62.55
Total Pu	4,171.20	208.57	436.46	4,816.23
²³⁸ U	20,436.28	16,922.47	30,246.90	67,605.65
Total (U + Pu)	24,607.48	17,131.04	30,683.36	72,421.88

Table 3-48. Discharge Mass Balance, kg
(Large Core, Ref Library, Cycle 2)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	1,521.04	134.83	213.57	1,869.44
²⁴⁰ Pu	473.04	2.71	4.57	480.32
²⁴¹ Pu	70.44	0.05	0.08	70.57
²⁴² Pu	31.54	0.00	0.00	31.54
Total Pu	2,096.06	137.59	218.22	2,451.87
²³⁸ U	9,987.04	8,423.34	15,123.45	33,533.83
Total (U + Pu)	12,083.10	8,560.93	15,341.67	35,985.70

Table 3-49. Mass Balance, kg
(Large Core, Ref Library, Cycle 3)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	3,104.49	70.28	213.57	3,388.34
²⁴⁰ Pu	819.92	0.69	4.57	825.18
²⁴¹ Pu	140.99	0.01	0.08	141.08
²⁴² Pu	61.74	0.00	0.00	61.74
Total Pu	4,127.14	70.98	218.22	4,416.34
²³⁸ U	21,354.28	17,074.75	30,490.10	68,919.13
Total (U + Pu)	25,481.42	17,145.73	30,708.32	73,335.47
<u>EOC</u>				
²³⁹ Pu	3,079.26	205.75	418.31	3,703.32
²⁴⁰ Pu	905.49	3.19	10.92	919.60
²⁴¹ Pu	140.09	0.06	0.27	140.42
²⁴² Pu	62.76	0.00	0.01	62.77
Total Pu	4,187.60	209.00	429.51	4,826.11
²³⁸ U	20,434.46	16,921.45	30,247.20	67,603.11
Total (U + Pu)	24,622.06	17,130.45	30,676.71	72,429.22

Table 3-50. Discharge Mass Balance, kg
(Large Core, Ref Library, Cycle 3)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	1,524.78	134.91	0.00	1,659.69
²⁴⁰ Pu	471.51	2.67	0.00	474.18
²⁴¹ Pu	70.24	0.05	0.00	70.29
²⁴² Pu	31.49	0.00	0.00	31.49
Total Pu	2,098.02	137.63	0.00	2,235.65
²³⁸ U	9,999.80	8,422.95	0.00	18,422.75
Total (U + Pu)	12,097.82	8,560.58	0.00	20,658.40

Table 3-51. Mass Balance, kg
(Large Core, Ref Library, Cycle 4)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	3,094.33	70.84	418.31	3,583.48
²⁴⁰ Pu	818.94	0.70	10.92	830.56
²⁴¹ Pu	140.77	0.01	0.27	141.05
²⁴² Pu	61.66	0.00	0.01	61.67
Total Pu	4,115.70	71.55	429.51	4,616.76
²³⁸ U	21,361.32	17,074.11	30,247.20	68,682.63
Total (U + Pu)	25,477.02	17,145.66	30,676.71	73,299.39
<u>EOC</u>				
²³⁹ Pu	3,070.75	209.87	608.64	3,889.26
²⁴⁰ Pu	902.88	3.43	20.99	927.30
²⁴¹ Pu	139.81	0.06	0.64	140.51
²⁴² Pu	62.66	0.00	0.02	62.68
Total Pu	4,176.10	213.36	630.29	5,019.75
²³⁸ U	20,457.08	16,916.10	30,000.58	67,373.76
Total (U + Pu)	24,633.18	17,129.46	30,630.87	72,393.51

Table 3-52. Discharge Mass Balance, kg
(Large Core, Ref Library, Cycle 4)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	1,530.39	137.17	391.84	2,059.40
²⁴⁰ Pu	474.17	2.71	16.45	493.33
²⁴¹ Pu	70.74	0.05	0.56	71.35
²⁴² Pu	31.74	0.00	0.02	31.76
Total Pu	2,107.04	139.93	408.87	2,655.84
²³⁸ U	9,993.30	8,419.97	14,881.90	33,295.17
Total (U + Pu)	12,100.34	8,559.90	15,290.77	35,951.01

Table 3-53. Mass Balance, kg
(Large Core, FF Library, Cycle 1)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	3,138.28	0.00	0.00	3,138.28
²⁴⁰ Pu	784.58	0.00	0.00	784.58
²⁴¹ Pu	144.55	0.00	0.00	144.55
²⁴² Pu	61.94	0.00	0.00	61.94
Total Pu	4,129.35	0.00	0.00	4,129.35
²³⁸ U	21,779.64	8,575.62	39,308.90	69,664.16
Total (U + Pu)	25,908.99	8,575.62	39,308.90	73,793.51
<u>EOC</u>				
²³⁹ Pu	3,121.34	140.56	223.62	3,485.52
²⁴⁰ Pu	876.28	1.44	2.44	880.16
²⁴¹ Pu	140.94	0.02	0.01	140.97
²⁴² Pu	63.06	0.00	0.00	63.06
Total Pu	4,201.62	142.02	226.07	4,569.71
²³⁸ U	20,828.37	16,998.94	30,489.70	68,317.01
Total (U + Pu)	25,029.99	17,140.96	30,715.77	72,886.72

Table 3-54. Discharge Mass Balance, kg
(Large Core, FF Library, Cycle 1)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	1,560.67	70.28	0.00	1,630.95
²⁴⁰ Pu	438.14	0.72	0.00	438.86
²⁴¹ Pu	70.47	0.01	0.00	70.48
²⁴² Pu	31.53	0.00	0.00	31.53
Total Pu	2,100.81	71.01	0.00	2,171.82
²³⁸ U	10,414.18	8,499.47	0.00	18,913.65
Total (U + Pu)	12,514.99	8,570.48	0.00	21,085.47

Table 3-55. Mass Balance, kg
(Large Core, FF Library, Cycle 2)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	3,139.32	70.28	223.62	3,433.22
²⁴⁰ Pu	832.80	0.72	2.44	835.96
²⁴¹ Pu	143.18	0.01	0.01	143.20
²⁴² Pu	62.69	0.00	0.00	62.69
Total Pu	4,177.99	71.01	226.07	4,475.07
²³⁸ U	21,292.03	17,075.08	30,489.70	68,856.81
Total (U + Pu)	25,470.02	17,146.09	30,715.77	73,331.88
<u>EOC</u>				
²³⁹ Pu	3,102.48	204.29	425.05	3,731.82
²⁴⁰ Pu	916.36	3.36	9.02	928.74
²⁴¹ Pu	141.87	0.05	0.16	142.08
²⁴² Pu	63.65	0.00	0.00	63.65
Total Pu	4,224.36	207.70	434.23	4,866.29
²³⁸ U	20,387.14	16,923.39	30,249.42	67,559.95
Total (U + Pu)	24,611.50	17,131.09	30,683.65	72,426.24

Table 3-56. Discharge Mass Balance, kg
(Large Core, FF Library, Cycle 2)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	1,533.71	134.19	212.53	1,880.43
²⁴⁰ Pu	477.69	2.67	4.51	484.87
²⁴¹ Pu	71.21	0.05	0.08	71.34
²⁴² Pu	31.98	0.00	0.00	31.98
Total Pu	2,114.59	136.91	217.12	2,468.62
²³⁸ U	9,972.07	8,424.08	15,124.71	33,520.86
Total (U + Pu)	12,086.66	8,560.99	15,341.83	35,989.48

Table 3-57. Mass Balance, kg
(Large Core, FF Library, Cycle 3)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	3,145.10	70.10	212.53	3,427.73
²⁴⁰ Pu	832.75	0.68	4.51	837.94
²⁴¹ Pu	143.26	0.01	0.08	143.35
²⁴² Pu	62.78	0.00	0.00	62.78
Total Pu	4,183.89	70.79	217.12	4,471.80
²³⁸ U	21,295.84	17,074.93	30,491.35	68,862.12
Total (U + Pu)	25,479.73	17,145.72	30,708.47	73,333.92
<u>EOC</u>				
²³⁹ Pu	3,107.19	205.28	416.85	3,729.32
²⁴⁰ Pu	916.37	3.34	10.80	930.51
²⁴¹ Pu	141.91	0.05	0.27	142.23
²⁴² Pu	63.72	0.00	0.01	63.73
Total Pu	4,229.19	208.67	427.93	4,865.79
²³⁸ U	20,391.47	16,922.05	30,249.03	67,562.55
Total (U + Pu)	24,620.66	17,130.72	30,676.96	72,428.34

Table 3-58. Discharge Mass Balance, kg
(Large Core, FF Library, Cycle 3)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	1,539.70	134.61	0.00	1,674.31
²⁴⁰ Pu	478.45	2.64	0.00	481.09
²⁴¹ Pu	71.37	0.04	0.00	71.41
²⁴² Pu	32.11	0.00	0.00	32.11
Total Pu	2,121.63	137.29	0.00	2,258.92
²³⁸ U	9,973.35	8,423.30	0.00	18,396.65
Total (U + Pu)	12,094.98	8,560.59	0.00	20,655.57

Table 3-59. Mass Balance, kg
(Large Core, FF Library, Cycle 4)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	3,143.59	70.67	416.85	3,631.11
²⁴⁰ Pu	831.94	0.70	10.79	843.43
²⁴¹ Pu	143.14	0.01	0.27	143.42
²⁴² Pu	62.72	--	0.01	62.73
Total Pu	4,181.39	71.38	427.92	4,680.69
²³⁸ U	<u>21,299.16</u>	<u>17,074.29</u>	<u>30,249.03</u>	<u>68,622.48</u>
Total (U + Pu)	25,480.55	17,145.67	30,676.95	73,303.17
<u>EOC</u>				
²³⁹ Pu	3,105.46	209.02	606.36	3,920.84
²⁴⁰ Pu	914.11	3.38	20.74	938.23
²⁴¹ Pu	141.70	0.05	0.63	142.38
²⁴² Pu	63.64	0.00	0.02	63.66
Total Pu	4,224.91	212.45	627.75	5,065.11
²³⁸ U	<u>20,411.87</u>	<u>16,917.07</u>	<u>30,003.68</u>	<u>67,332.62</u>
Total (U + Pu)	24,636.78	17,129.52	30,631.43	72,397.73

Table 3-60. Discharge Mass Balance, kg
(Large Core, FF Library, Cycle 4)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	1,539.47	136.69	390.37	2,066.53
²⁴⁰ Pu	476.97	2.68	16.25	495.90
²⁴¹ Pu	71.18	0.05	0.55	71.78
²⁴² Pu	32.04	0.00	0.02	32.06
Total Pu	2,119.66	139.42	407.19	2,666.27
²³⁸ U	<u>9,984.47</u>	<u>8,420.54</u>	<u>14,884.04</u>	<u>33,289.05</u>
Total (U + Pu)	12,104.13	8,559.96	15,291.23	35,955.32

Table 3-61. Mass Balance, kg
(Large Core, Pu Library, Cycle 1)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	3,361.62	0.00	0.00	3,361.62
²⁴⁰ Pu	840.41	0.00	0.00	840.41
²⁴¹ Pu	154.84	0.00	0.00	154.84
²⁴² Pu	66.35	0.00	0.00	66.35
Total Pu	4,423.22	0.00	0.00	4,423.22
²³⁸ U	21,498.73	17,151.24	30,733.28	69,383.25
Total (U + Pu)	25,921.95	17,151.24	30,733.28	73,806.47
<u>EOC</u>				
²³⁹ Pu	3,215.94	136.84	217.60	3,570.38
²⁴⁰ Pu	1,007.69	2.02	3.42	1,013.13
²⁴¹ Pu	151.68	0.02	0.03	151.73
²⁴² Pu	67.42	0.00	0.00	67.42
Total Pu	4,442.73	138.88	221.05	4,802.66
²³⁸ U	20,603.36	17,002.17	30,494.89	68,100.42
Total (U + Pu)	25,046.09	17,141.05	30,715.94	72,903.08

Table 3-62. Discharge Mass Balance, kg
(Large Core, Pu Library, Cycle 1)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	1,607.97	68.42	0.00	1,676.39
²⁴⁰ Pu	503.85	1.01	0.00	504.86
²⁴¹ Pu	75.84	0.01	0.00	75.85
²⁴² Pu	33.71	0.00	0.00	33.71
Total Pu	2,221.37	69.44	0.00	2,290.81
²³⁸ U	10,301.68	8,501.08	0.00	18,802.76
Total (U + Pu)	12,523.05	8,570.52	0.00	21,093.57

Table 3-63. Mass Balance, kg
(Large Core, Pu Library, Cycle 2)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	3,251.95	68.42	217.60	3,537.97
²⁴⁰ Pu	914.84	1.01	3.42	919.27
²⁴¹ Pu	151.57	0.01	0.03	151.61
²⁴² Pu	66.16	0.00	0.00	66.16
Total Pu	4,384.52	69.44	221.05	4,675.01
²³⁸ U	21,097.33	17,076.70	30,494.89	68,668.92
Total (U + Pu)	25,481.85	17,146.14	30,715.94	73,343.93
<u>EOC</u>				
²³⁹ Pu	3,114.89	199.83	414.20	3,728.92
²⁴⁰ Pu	1,063.80	4.74	12.70	1,081.24
²⁴¹ Pu	152.25	0.07	0.22	152.54
²⁴² Pu	67.03	0.00	0.01	67.04
Total Pu	4,397.97	204.64	427.13	5,029.74
²³⁸ U	20,226.66	16,926.81	30,257.52	67,410.99
Total (U + Pu)	24,624.63	17,131.45	30,684.65	72,440.73

Table 3-64. Discharge Mass Balance, kg
(Large Core, Pu Library, Cycle 2)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	1,533.46	132.36	207.10	1,872.92
²⁴⁰ Pu	573.19	3.77	6.35	583.31
²⁴¹ Pu	78.24	0.06	0.11	78.41
²⁴² Pu	34.15	0.00	0.00	34.15
Total Pu	2,219.04	136.19	213.56	2,568.79
²³⁸ U	9,876.88	8,426.58	15,128.76	33,432.22
Total (U + Pu)	12,095.92	8,562.77	15,342.32	36,001.01

Table 3-65. Mass Balance, kg
(Large Core, Pu Library, Cycle 3)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	3,278.80	68.95	207.10	3,554.85
²⁴⁰ Pu	914.96	0.97	6.35	922.28
²⁴¹ Pu	152.19	0.01	0.11	152.31
²⁴² Pu	<u>66.38</u>	<u>0.00</u>	<u>0.00</u>	<u>66.38</u>
Total Pu	4,412.33	69.93	213.56	4,695.82
²³⁸ U	<u>21,078.31</u>	<u>17,075.84</u>	<u>30,495.41</u>	<u>68,649.56</u>
Total (U + Pu)	25,490.64	17,145.77	30,708.97	73,345.38
<u>EOC</u>				
²³⁹ Pu	3,135.35	200.50	406.19	3,742.04
²⁴⁰ Pu	1,064.39	4.71	15.13	1,084.23
²⁴¹ Pu	152.65	0.07	0.35	153.07
²⁴² Pu	<u>67.23</u>	<u>0.00</u>	<u>0.01</u>	<u>67.24</u>
Total Pu	4,419.62	205.28	421.68	5,046.58
²³⁸ U	<u>20,213.11</u>	<u>16,925.81</u>	<u>30,257.79</u>	<u>67,396.71</u>
Total (U + Pu)	24,632.73	17,131.09	30,679.47	72,443.29

Table 3-66. Discharge Mass Balance, kg
(Large Core, Pu Library, Cycle 3)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	1,514.75	131.49	0.00	1,646.24
²⁴⁰ Pu	559.07	3.73	0.00	562.80
²⁴¹ Pu	76.29	0.06	0.00	76.35
²⁴² Pu	<u>33.30</u>	<u>0.00</u>	<u>0.00</u>	<u>33.30</u>
Total Pu	2,183.41	135.28	0.00	2,318.69
²³⁸ U	<u>9,925.53</u>	<u>8,425.66</u>	<u>0.00</u>	<u>18,351.19</u>
Total (U + Pu)	12,108.94	8,560.94	0.00	20,669.88

Table 3-67. Mass Balance, kg
(Large Core, Pu Library, Cycle 4)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>BOC</u>				
²³⁹ Pu	3,238.89	69.01	406.19	3,714.09
²⁴⁰ Pu	909.90	0.98	15.13	926.01
²⁴¹ Pu	150.90	0.01	0.35	151.26
²⁴² Pu	65.87	0.00	0.01	65.88
Total Pu	4,365.56	70.00	421.68	4,857.24
²³⁸ U	21,115.56	17,075.78	30,257.79	68,449.13
Total (U + Pu)	25,481.12	17,145.78	39,679.47	73,306.37
<u>EOC</u>				
²³⁹ Pu	3,105.83	203.23	588.06	3,897.12
²⁴⁰ Pu	1,056.88	4.74	28.99	1,090.61
²⁴¹ Pu	151.46	0.07	0.84	152.37
²⁴² Pu	66.73	0.00	0.02	66.75
Total Pu	4,380.90	208.04	617.91	5,206.85
²³⁸ U	20,256.27	16,922.15	30,018.04	67,196.46
Total (U + Pu)	24,637.17	17,130.19	30,635.95	72,403.31

Table 3-68. Discharge Mass Balance, kg
(Large Core, Pu Library, Cycle 4)

	<u>Core</u>	<u>Axial blanket</u>	<u>Radial blanket</u>	<u>Total</u>
<u>EOC</u>				
²³⁹ Pu	1,543.79	132.84	378.30	2,054.93
²⁴⁰ Pu	574.42	3.75	22.72	600.89
²⁴¹ Pu	78.62	0.06	0.73	79.41
²⁴² Pu	34.36	0.00	0.02	34.38
Total Pu	2,231.19	136.65	401.77	2,769.61
²³⁸ U	9,869.05	8,423.80	14,893.12	33,185.97
Total (U + Pu)	12,100.24	8,560.45	15,294.89	35,955.58

Table 3-69. EC-EOC Discharge Pu Isotopic Mixes
(Core Average, atom %)

Small Core			
Isotope	Library		
	Ref	FF	Pu
239	69.5	71.9	68.9
240	25.2	23.0	25.9
241	3.6	3.5	3.6
242	1.7	1.6	1.6
Large Core			
Isotope	Library		
	Ref	FF	Pu
239	72.6	72.6	69.2
240	22.5	22.5	25.8
241	3.4	3.4	3.5
242	1.5	1.5	1.5

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8. Combustion Engineering, Inc.
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Barringer, HS	Neuhold, RJ
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Central Files (6)	Poor, HH/Alliance
Colpo, PN	Probert, PB/Barberton
Engelder, TC	Rowand, WH
Green, ID	Roy, DH (2)
Holt, CD	Stewart, JE
Hostetler, DR	Tilford, JM
Jacobsen, JA	Travis, CC/TRG
Library (2)	Webb, RA
Littrell, LW (2)	Whitaker, BW
Livolsi, AZ	Wolfe, GE