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FINAL REPORT

**Evaluation of Mixed MOX-LEU Loading
Patterns for LWRs Originating from
Inability to Deliver MOX Assemblies:
GE BWR/6 Reload Core Study**

**Imelda Ariani
Paul J. Turinsky**

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FINAL REPORT

**EVALUATION OF MIXED MOX-LEU LOADING PATTERNS
FOR LWRs ORIGINATING FROM INABILITY
TO DELIVER MOX ASSEMBLIES: GE BWR/6
RELOAD CORE STUDY**

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GE BWR/6 Reload Core Study

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September, 1999

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1. Introduction

This study is in support of the weapon's grade Pu disposition project utilizing the reactor option, which entails burning weapon's grade Mixed Oxide (MOX) fuel in Light Water Reactors (LWRs). What is being evaluated is the feasibility of substituting Low Enriched Uranium (LEU) fuel assemblies for weapon's grade MOX assemblies starting from an equilibrium cycle, full MOX core. The specific focus of this report is on the GE Boiling Water Reactor (BWR) core design, starting with an equilibrium cycle, full MOX core identified by GE. The motivation for this study is two fold. Firstly, since there are technical and political uncertainties associated with the utilization of weapon's grade MOX assemblies, there is a potential that some or all of the feed fuel assemblies associated with a reload region may not be available in a timely manner. This condition will be referred to, as the disruption scenario. Secondly, at the conclusion of the Pu disposition campaign, the reactors involved will need to transition back to full LEU cores. Either condition will result in the insertion of feed LEU assemblies in a core containing once and twice burnt weapon's grade MOX assemblies. There are known design challenges associated with mixed MOX-LEU cores. The emphasis of the current study is noted to be related to the transition from an equilibrium cycle, full MOX core to an equilibrium cycle, full LEU core, with the additional complexity of not knowing when this will occur for the disruption scenario.

The design features of interest include the lattice design, core loading pattern (LP), and control rod pattern (CRP). The lattice design involves the placement of fuel and burnable poison (BP) material within the fuel lattice. The MOX lattice designs used in this study have been restricted to the existing GE designs used in their full MOX core study. The LEU lattice designs were created based upon the MOX lattice designs, as described in Section 3. In determining the LP, most active LP constraints have been imposed, the exception being the cold shutdown margin constraint. The CRP is determined utilizing FORMOSA-B's CRP search capability for conventional cores.

2. Methodology

Core models are established by generating two-group, homogenized cross-sections via the lattice physics code HELIOS [3], and solving the two-group neutron diffusion equation via the core simulator code FORMOSA-B [5]. Linkage codes ZENITH [3] and FORCIP-B [4] are also used to process the cross sections to the form required by FORMOSA-B.

FORMOSA-B is capable of optimizing the fuel loading pattern (LP) for a BWR while simultaneously determining the Control Rod Patterns (CRP). It also differs from FORMOSA-P in the following manners: 3-D, only macroscopic depletion capability, full two-phase flow model with inlet flow redistribution, critical flow search, usage of BWR relevant objectives and constraints, and peak pin-to-box pin reconstruction.

3. Lattice Physics Calculations

Lattice physics calculations for MOX fuel lattices were completed by the team from Oak Ridge National Laboratory utilizing HELIOS/ZENITH codes. LEU lattice designs and calculations were completed by the author. The MOX fuel lattice designs were taken from the UO₂-like MOX fuel bundle designs from the GE report [6]. Each LEU lattice is designed such that the LEU lattice's k_{inf} at the end of one cycle of exposure will be approximately the same as the MOX lattice's k_{inf} it is substituting for. This is done for each MOX lattice design to generate the equivalent LEU lattice design. HELIOS lattice physics calculations were then completed for a range of LEU lattice designs determined by perturbing slightly up and down the fuel pin enrichments for the equivalent LEU lattices, thereby generating an inventory of LEU lattices with slightly different reactivities. This was necessary since FORMOSA-B does not treat the assembly enrichment as a continuous variable since BWR assemblies employ multiple pin enrichments and axially segmented lattice designs, hence the concept of an assembly enrichment is not applicable. Thus, the user must carefully select the feed fuel assembly

designs to employ or allow FORMOSA-B to select from an inventory of assembly designs the appropriate mix, to satisfy the cycle energy requirements. For both MOX and LEU lattice designs, integral gadolinia burnable absorbers in the UO_2 rods are employed. This was done to avoid using integral burnable absorber in MOX pins, a restriction placed on the design by DOE due to lack of burnup experience for such a configuration. For each lattice design, the lattice was depleted to high burnup at base case conditions, *i.e.* Hot Full Power (HFP) average moderator density and fuel temperature. Multiple instantaneous branch cases were executed during the depletion, enabling characterization of the cross-sections as a function of moderator density, fuel temperature, void fraction, and rodded/unrodded configuration within FORMOSA-B in order to apply spatially dependent, feedback corrections. Specifically for each lattice type, one base and six branch cases calculations were performed (Table 3.1). This was done for three unrodded depletions utilizing different void fractions. In addition, a rodded depletion at each void fraction was completed, with an instantaneous branch to the unrodded state.

TABLE 3.1: Instantaneous Branch Case Parameters for HELIOS BWR Lattice Calculations

CASE	$T_{\text{FUEL}}(\text{K})$	Void* Fraction	Rodded (Y/N)	Power Level W/g
BASE	792.5	0%	N	26.47
BRANCH 1: VOID LOW	792.5	40%	N	26.47
BRANCH 2: VOID HIGH	792.5	70%	N	26.47
BRANCH 3: T_{FUEL} DECREASE	560.0	0%	N	26.47
BRANCH 4: CONTROLLED HFP	792.5	0%	Y	26.47
BRANCH 5: UNCONTROLLED CZP	293.0	0%	N	0.0
BRANCH 6: CONTROLLED CZP	293.0	0%	Y	0.0
HFP RODDED DEPLETION	792.5	0%	Y	26.47

Note: three void fractions (0%, 40%, 70%) depletions required

The FORMOSA-B Cross Section Interface Program (FORCIP-B) has been modified to read the ZENITH outputs.

4. Equilibrium Cycle, Full MOX Core

Table 4.1 provides the core design and operating parameters assumed throughout this study. A FORMOSA-B model has been established for an equilibrium cycle, full MOX core loading pattern identified by GE.

TABLE 4.1: GE BWR Core Design and Operating Parameters

Parameter	Value
Power level	3833 MWth
System pressure	1047 psia
100% Core coolant flow rate	112.5 Mlbm/hr
Coolant inlet subcooling	21.23 Btu/lbm
Fraction of power generated in fuel rods	0.98
Fraction of power deposited in bypass flow regions	0.02
Target cycle length	12,350 MWd/ST
Number of fuel assemblies	800
Number of feed assemblies	264
Fuel lattice	9x9
Fuel rods per assembly	74
Active fuel height	150 in.
Core loading	169.3 ST
MLHGR limit	14.4 kW/ft. (operating limit) 12.96 kW/ft. (design target)
MCPR limit	1.29 (operating limit) 1.387 (design target)

The BWR-6 equilibrium cycle full MOX core was developed utilizing the FORMOSA-B code using the LP and shuffle instructions (Figure 4.2 and Figure 4.3, respectively) provided by GE. Note that the LP in Figure 4.2 is different from the LP in Figure 1.1.5-1 of the GE Report [6], since GE could not locate the shuffle instructions for

the LP presented in the GE Report. The process involved in obtaining the equilibrium cycle full MOX core is shown in Figure 4.1. For the initial guess, the bundle burnup values for all axial nodes within the bundle were set to the following values: 12350 MWd/ST, 24700 MWd/ST, and 37050 MWd/ST for once-, twice, and thrice-burnt assemblies, respectively. Utilizing the multicycle restart and the CRP search capabilities for a Conventional Core in FORMOSA-B, we iterated the cycle depletions and CRP optimizations until convergence was achieved. The control rod sequence exchanges are performed at the end of each 1.5 GWd/ST depletion. The sequence chosen follows the control rod exchange sequence presented in the GE Report, *i.e.* $A2 \rightarrow B1 \rightarrow A1 \rightarrow B2 \rightarrow A2 \rightarrow \text{etc.}$ During depletions, the core flow rates are adjusted to meet the target k_{eff} . The target k_{eff} is kept at 1.000 throughout the cycle since bias values applicable to FORMOSA-B could not be developed based upon the data available.

The equilibrium cycle, full MOX core results are presented in Figure 4.4 and Table 4.2. The Critical Power Ratio (CPR) predictions are based upon the GEXL correlation applicable to GE-11 bundles, which was provided to us by GE and incorporated into the FORMOSA-B code. The R-factor data required for GEXL calculations are assumed to be independent of notch insertions.

Table 4.2 indicates that the core flows required to achieve criticality are acceptable, utilizing low flows earlier in the cycle to maximize spectral shift production of plutonium and higher flows later in the cycle to retain criticality. Table 4.2 also presents the thermal limits (MFLPD: Maximum Fraction of Linear Power Density, MAPRAT: maximum fraction of average linear power density, MFLCPR: Maximum Fraction of Limiting Critical Power Ratio, Max. LHGR: Maximum Linear Heat Generation Rate, and MCPR), where it is to be noted that all thermal margins are less than or about 0.95. The value of the thermal margins are comparable to the values presented in the GE Report. Since we are using a different LP and CRPs, one would not expect them to be exactly the same. We conclude that we have established a feasible full MOX core FORMOSA-B model, which will serve as the basis for subsequent, disruption scenario studies.

FIGURE 4.1. Process Diagram for Obtaining the Equilibrium Cycle, Full MOX Core

		First Index															
		16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
S e c o n d I n d e x	16	2	1	1	1	1	1	1	2	F	2	F	2	F	1	F	2
	15	1	F	2	F	2	F	2	F	2	F	2	F	2	F	1	3
	14	1	2	1	1	1	1	1	1	F	1	F	1	F	2	2	
	13	1	F	1	F	2	F	2	F	2	F	2	F	2	1	2	
	12	1	2	1	2	1	1	1	1	F	1	F	1	F	1	2	
	11	1	F	1	F	1	F	2	F	2	F	2	F	2	1	2	
	10	1	2	1	2	1	2	F	1	F	1	F	1	F	1	2	
	9	2	F	1	F	1	F	1	F	2	F	2	F	1	2		
	8	F	2	F	2	F	2	F	2	F	1	F	1	2			
	7	2	F	1	F	1	F	1	F	1	F	2	1	2			
	6	F	2	F	2	F	2	F	2	F	2	F	1	2			
	5	2	F	1	F	1	F	1	F	1	1	1	2				
	4	F	2	F	2	F	2	F	1	2	2	2					
	3	1	F	2	1	1	1	1	2								
	2	F	1	2	2	2	2	2									
	1	2	3														

The numbers represent the number of previous cycles the bundle has been in the core. The symbol F denotes fresh fuels.

FIGURE 4.2. Equilibrium Cycle, Full MOX Core Loading Pattern

		First Index															
		16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
S e c o n d I n d e x	16	12,12	9,11	5,11	8,12	7,7	7,13	6,8	13,16	F	7,8	F	5,14	F	11,15	F	11,12
	15	11,9	F	5,12	F	15,16	F	12,14	F	12,16	F	5,8	F	5,7	F	3,15	6,7
	14	11,5	12,5	13,13	7,11	4,6	9,13	4,14	8,8	F	7,9	F	8,16	F	3,10	13,14	
	13	12,8	F	11,7	F	5,10	F	10,14	F	14,16	F	3,16	F	4,9	5,13	7,14	
	12	15,15	16,15	16,4	10,5	6,6	8,14	4,12	6,12	F	7,15	F	6,10	F	10,10	9,14	
	11	13,7	F	13,9	F	14,8	F	10,12	F	10,16	F	3,13	F	2,15	5,15	7,10	
	10	8,6	14,12	14,4	14,10	12,4	12,10	F	6,14	F	11,13	F	9,15	F	4,10	9,10	
	9	16,13	F	11,11	F	12,6	F	14,6	F	3,12	F	3,11	F	5,9	7,12		
	8	F	16,12	F	16,14	F	16,10	F	12,3	F	6,16	F	8,10	11,16			
	7	8,7	F	9,7	F	15,7	F	13,11	F	16,6	F	5,6	13,15	11,14			
	6	F	8,5	F	16,3	F	13,3	F	11,3	F	6,5	F	2,16	9,12			
	5	14,5	F	16,8	F	10,6	F	15,9	F	10,8	15,13	16,2	14,14				
	4	F	7,5	F	9,4	F	15,2	F	9,5	16,11	14,11	12,9					
	3	15,11	F	10,3	13,5	9,9	15,5	10,4	12,7								
	2	F	15,3	14,13	14,7	14,9	10,7	10,9									
	1	12,11	7,6														

The two numbers represent the location of the bundle in the previous cycle.

FIGURE 4.3. Equilibrium Cycle, Full MOX Core Shuffle Instructions

FIGURE 4.4. Equilibrium Cycle, Full MOX Core Control Rod Patterns

TABLE 4.2: Equilibrium Cycle, Full MOX Core's Key Attributes

Cycle Exposure (GWd/ST)	% Rated Core Flow	MFLPD	MAPRAT	MFLCPR	Max. LHGR kw/ft.	MCPR	k_{eff}(ARO, 100% Core Flow)
0	83.3422	0.9347	0.8593	0.9317	12.11	1.49	1.0188
1.5	83.1626	0.8763	0.7978	0.9057	11.36	1.53	1.0204
3.0	83.5822	0.9058	0.7999	0.9195	11.74	1.51	1.0167
4.5	93.3264	0.8964	0.8793	0.8689	11.62	1.60	1.0141
6.0	84.0028	0.8986	0.8787	0.9020	11.65	1.54	1.0129
7.5	94.5321	0.9033	0.8741	0.9298	11.71	1.49	1.0130
9.0	86.2311	0.8526	0.8309	0.9326	11.05	1.49	1.0121
10.5	86.9833	0.8933	0.7979	0.8933	11.58	1.56	1.0084
11.5	94.3653	0.8475	0.8090	0.8753	10.98	1.59	1.0040
12.35	103.8140	0.8134	0.8396	0.8674	10.54	1.60	0.9992

5. Initial Mixed MOX-LEU Core

In the first cycle in which the LEU feed assemblies are loaded into the core, all MOX feed assemblies are assumed to be unavailable and replaced by LEU feed assemblies. This will be referred to as the initial mixed MOX-LEU core. For the initial mixed MOX-LEU core, the following design approach was employed. Since there is no information available from the GE Report or elsewhere regarding the LEU fuel assembly design, we have to design the LEU assemblies ourselves. For each MOX fuel bundle, there are three lattice designs which correspond to three elevation spans: upper, middle, and lower. There are four enrichment types of MOX pins, 2.3, 3.6, 4.0, and 5.4 w/o WGPu, used in the three lattices of the MOX fuel bundle. To approximately determine the ²³⁵U

enrichment of the LEU pins equivalent to the MOX pins, which will be used when replacing the MOX pins in developing the LEU lattices, we developed a lattice which has an equivalent LEU pin enrichment for each of the MOX pin enrichments. We accomplished this equivalence by utilizing HELIOS to obtain the ^{235}U enrichment for a uniform pin-wise enrichment distribution LEU lattice which produces approximately the same k_{inf} as the uniform pin-wise enrichment distribution MOX lattice for each of the MOX pin enrichment (at the end of one cycle of exposure, which is $\sim 17\text{GWd/MT}$). The results are summarized in Figure 5.1.

FIGURE 5.1. LEU vs. MOX Pins k_{inf}

The MOX pins in the three MOX lattices are then replaced by their equivalent LEU pins to create the LEU lattices. Similar to the original MOX lattice design, all LEU rods which replace the MOX pins are also axially uniform. Modifications also need to be completed for Gd pins, due to differences in Gd worth and burnout rate in LEU versus MOX lattices. The LEU lattices will need less Gd pins since the gadolinia is worth more in the softer energy spectrum of an LEU versus MOX lattice. There are 16 Gd rods in the

MOX design (Figure 5.2); whereas, the LEU design producing nearly equivalent reactivity hold-down at BOL was determined to have six less Gd rods (Figure 5.3). Note that the ^{235}U enrichments in the UO_2 pins which previously contained gadolinia are kept the same as the original values. Therefore, the enrichment for an LEU pin in locations where Gd pins previously existed is not axially uniform. The gadolinium enrichment in the Gd rods also needs to be increased to accommodate the fact that the LEU lattice burns out the gadolinia faster than the MOX lattice due to the softer energy spectrum. This fact is supported by results in Figure 5.4. Figure 5.5 presents the peak relative pin power versus burnup for the axially lower MOX lattice and various Gd rod designs for the LEU lattices. The Gd loading modifications required to produce approximately the same burnout rate, hence hot excess core reactivity, are summarized in Table 5.1. The resulting lattices that produce equivalent LEU lattices to the MOX lattices will be referred to as enrichment 1 lattices, whose enrichment distributions are shown in Figure 5.6.

TABLE 5.1: Gd Loading Modifications

Lattice	Number of Gd Rods		Gd w/o	
	MOX	LEU	MOX	LEU
Upper	16	10	3.5	4.5
Middle	16	10	3.5	5.0
Lower	16	10	4.5	6.5

FIGURE 5.2. Gd Loading for MOX Lattices

FIGURE 5.3. Gd Loading for LEU Lattices

FIGURE 5.4. Lower Lattice LEU vs. MOX Lattice k_{inf} (Uncontrolled, HFP, 0% Void)

FIGURE 5.5. Lower Lattice LEU vs. MOX Lattice Peak Pin Power (Uncontrolled, HFP, 0% Void)

Upper

2.20	3.00	3.60	4.20	4.20	4.20	3.60	3.00	2.20
	VR	3.40	4.95*	VR	4.95*	3.40	VR	3.00
		4.60	4.60	4.95	4.60	4.95*	3.40	3.60
			4.95	W	W	4.60	4.95*	4.20
				W	W	4.95	VR	4.20
					4.95	4.60	4.95*	4.20
Numbers shown are U-235w/o						4.60	3.40	3.60
VR = Vanished Region							VR	3.00
* Gd 4.5w/o								2.20

Middle

2.20	3.00	3.60	4.20	4.20	4.20	3.60	3.00	2.20
	2.40	3.40	4.40*	4.40	4.40*	3.40	2.40	3.00
		4.60	4.60	4.40	4.60	4.40*	3.40	3.60
			4.40	W	W	4.60	4.40*	4.20
				W	W	4.40	4.40	4.20
					4.40	4.60	4.40*	4.20
						4.60	3.40	3.60
							2.40	3.00
* Gd 5.0w/o								2.20

Lower

2.20	3.00	3.60	4.20	4.20	4.20	3.60	3.00	2.20
	2.40	3.40	3.60*	4.40	3.60*	3.40	2.40	3.00
		4.60	4.60	3.60	4.40	3.60*	3.40	3.60
			3.60	W	W	4.60	3.60*	4.20
				W	W	3.60	4.40	4.20
					3.60	4.60	3.60*	4.20
						4.60	3.40	3.60
							2.40	3.00
* Gd 6.5w/o								2.20

FIGURE 5.6. LEU Enrichment 1 Fuel Bundle Composition

Since FORMOSA-B does not complete an enrichment search, the mean enrichment for the LEU feed assemblies which will meet the cycle energy production requirement and other constraints has to be predetermined. This can be done by providing FORMOSA-B with two LEU feed fuel bundle designs, one with excess reactivity and the other with deficient reactivity with regard to meeting the cycle energy production requirement and determining the appropriate mix to satisfy the cycle energy requirement. Two sets of LEU lattice cross sections were generated for this purpose, obtained by increasing or decreasing the pin-wise ^{235}U enrichment uniformly throughout the lattice from those used in the enrichment 1 lattices. Enrichment 2 (Figure 5.7) is generated by subtracting 0.15 w/o ^{235}U from every LEU pin, while enrichment 3 (Figure 5.8) is generated by adding 0.15 w/o ^{235}U to every LEU pin. This results in a maximum 5.10 w/o ^{235}U pin enrichment, which slightly exceeds the fuel fabrication plant's current critical material license. Given the continuing need to increase the critical material license enrichment limit as required to support higher discharge burnups and the fact that the maximum enrichment occurs in a Gd rod, this slight violation should present no practical problem. Figure 5.9 present the lattice k_{inf} versus burnup for the axially lower MOX lattice and axially lower LEU enrichments 1,2 and 3 lattices, displaying the desired "bracketing" of the MOX lattice behavior.

Due to the limited time available, we did not utilize FORMOSA-B's capability to perform an LP search. Instead, the burned fuel bundles are kept at their original locations as defined in the equilibrium cycle, full MOX core LP (Figure 4.3). The mix of the two LEU assembly enrichments are varied such that the EOC core flow requirement is met. For each feed fuel variation, the CRP search capability in FORMOSA-B is utilized. Similar to the equilibrium cycle, full MOX core, the target k_{eff} is 1.000 throughout the cycle depletion.

The CRP and LP for the resulting LP for the initial mixed MOX-LEU core are shown in Figure 5.10 and Figure 5.11, respectively. The core's key attributes are summarized in Table 5.2. MFLPD, MAPRAT, MFLCPR, maximum LHGR, minimum

CPR and core flow values are comparable with the equilibrium cycle, full MOX core's values. Therefore, we conclude that a feasible initial mixed MOX-LEU core has been determined.

The resulting LP for the initial mixed MOX-LEU core is the starting point for the optimization of subsequent cycles as now explained.

Upper

2.05	2.85	3.45	4.05	4.05	4.05	3.45	2.85	2.05
	VR	3.25	4.80*	VR	4.80*	3.25	VR	2.85
		4.45	4.45	4.80	4.45	4.80*	3.25	3.45
			4.80	W	W	4.45	4.80*	4.05
				W	W	4.80	VR	4.05
					4.80	4.45	4.80*	4.05
Numbers shown are U-235w/o						4.45	3.25	3.45
VR = Vanished Region							VR	2.85
* Gd 4.5w/o								2.05

Middle

2.05	2.85	3.45	4.05	4.05	4.05	3.45	2.85	2.05
	2.25	3.25	4.25*	4.25	4.25*	3.25	2.25	2.85
		4.45	4.45	4.25	4.45	4.25*	3.25	3.45
			4.25	W	W	4.45	4.25*	4.05
				W	W	4.25	4.25	4.05
					4.25	4.45	4.25*	4.05
						4.45	3.25	3.45
							2.25	2.85
* Gd 5.0w/o								2.05

Lower

2.05	2.85	3.45	4.05	4.05	4.05	3.45	2.85	2.05
	2.25	3.25	3.45*	4.25	3.45*	3.25	2.25	2.85
		4.45	4.45	3.45	4.25	3.45*	3.25	3.45
			3.45	W	W	4.45	3.45*	4.05
				W	W	3.45	4.25	4.05
					3.45	4.45	3.45*	4.05
						4.45	3.25	3.45
							2.25	2.85
* Gd 6.5w/o								2.05

FIGURE 5.7. LEU Enrichment 2 Fuel Bundle Composition

Upper

2.35	3.15	3.75	4.35	4.35	4.35	3.75	3.15	2.35
	VR	3.55	5.10*	VR	5.10*	3.55	VR	3.15
		4.75	4.75	5.10	4.75	5.10*	3.55	3.75
			5.10	W	W	4.75	5.10*	4.35
				W	W	5.10	VR	4.35
					5.10	4.75	5.10*	4.35
Numbers shown are U-235w/o						4.75	3.55	3.75
VR = Vanished Region							VR	3.15
* Gd 4.5w/o								2.35

Middle

2.35	3.15	3.75	4.35	4.35	4.35	3.75	3.15	2.35
	2.55	3.55	4.55*	4.55	4.55*	3.55	2.55	3.15
		4.75	4.75	4.55	4.75	4.55*	3.55	3.75
			4.55	W	W	4.75	4.55*	4.35
				W	W	4.55	4.55	4.35
					4.55	4.75	4.55*	4.35
						4.75	3.55	3.75
							2.55	3.15
* Gd 5.0w/o								2.35

Lower

2.35	3.15	3.75	4.35	4.35	4.35	3.75	3.15	2.35
	2.55	3.55	3.75*	4.55	3.75*	3.55	2.55	3.15
		4.75	4.75	3.75	4.55	3.75*	3.55	3.75
			3.75	W	W	4.75	3.75*	4.35
				W	W	3.75	4.55	4.35
					3.75	4.75	3.75*	4.35
						4.75	3.55	3.75
							2.55	3.15
* Gd 6.5w/o								2.35

FIGURE 5.8. LEU Enrichment 3 Fuel Bundle Composition

FIGURE 5.9. Lower Lattice k_{inf} for Different LEU Enrichments (Uncontrolled, HFP, 0% Void)

TABLE 5.2: Initial Mixed MOX-LEU Core's Key Attributes

Cycle Exposure (GWd/ST)	% Rated Core Flow	MFLPD	MAPRAT	MFLCPR	Max. LHGR kw/ft.	MCPR	k_{eff} (ARO, 100% Core Flow)
0	84.097	0.928	0.825	0.908	12.029	1.531	1.0218
1.5	84.063	0.944	0.852	0.942	12.231	1.476	1.0283
3.0	85.042	0.931	0.836	0.932	12.061	1.492	1.0271
4.5	85.551	0.847	0.822	0.913	10.973	1.522	1.0263
6.0	91.116	0.829	0.803	0.933	10.748	1.490	1.0265
7.5	86.545	0.858	0.895	0.939	11.123	1.480	1.0268
9.0	99.769	0.807	0.821	0.930	10.462	1.494	1.0234
10.5	87.864	0.804	0.780	0.920	10.421	1.511	1.0152
11.5	94.142	0.779	0.781	0.888	10.100	1.565	1.0082
12.35	105.422	0.726	0.812	0.863	9.403	1.611	1.0016

FIGURE 5.10. Initial Mixed Core Control Rod Patterns

		First Index															
		16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
S e c o n d I n d e x	16	2	1	1	1	1	1	1	2	F2	2	F3	2	F3	1	F3	2
	15	1	F2	2	F2	2	F2	2	F2	2	F2	2	F2	2	F3	1	3
	14	1	2	1	1	1	1	1	1	F2	1	F2	1	F3	2	2	
	13	1	F2	1	F2	2	F2	2	F2	2	F2	2	F3	2	1	2	
	12	1	2	1	2	1	1	1	1	F2	1	F2	1	F3	1	2	
	11	1	F2	1	F2	1	F2	2	F2	2	F2	2	F3	2	1	2	
	10	1	2	1	2	1	2	F3	1	F3	1	F3	1	F3	1	2	
	9	2	F2	1	F2	1	F2	1	F3	2	F3	2	F3	1	2		
	8	F2	2	F2	2	F2	2	F3	2	F3	1	F3	1	2			
	7	2	F2	1	F2	1	F2	1	F3	1	F3	2	1	2			
	6	F3	2	F2	2	F2	2	F3	2	F3	2	F3	1	2			
	5	2	F2	1	F3	1	F3	1	F3	1	1	1	2				
	4	F3	2	F3	2	F3	2	F3	1	2	2	2					
	3	1	F3	2	1	1	1	1	2								
	2	F3	1	2	2	2	2	2									
	1	2	3														

The numbers represent the number of previous cycles the bundle has been in the core. The symbol F denotes fresh fuels.

F2 = LEU Enrichment 2 (Figure 5.7)

F3 = LEU Enrichment 3 (Figure 5.8)

FIGURE 5.11. Initial Mixed MOX-LEU Core Loading Pattern

6. Subsequent Mixed MOX-LEU Cores

Similar to the mixed MOX-LEU core studies completed for PWRs [1 and 2], starting with the initial mixed MOX-LEU core defined in Section 5, two scenarios (see Figure 6.1) are introduced in regard to availability of MOX feed assemblies in the subsequent cycle: (1) assume that MOX feed batches are available and (2) assume that MOX feed batches continue to be unavailable. MOX lattice designs are limited to MOX designs used in the GE BWR-6 equilibrium cycle, full MOX core and LEU lattice designs are limited to the two designs described in Section 5. This was done to determine if acceptable LPs could be determined without the need to develop new and more complex lattice designs.

FIGURE 6.1. Mixed MOX-LEU Core Disruption Scenarios

6.1 Scenario 1: MOX Feed Assemblies Available for Subsequent Cycles

For scenario 1 cores, the LP is created by using the shuffle instructions shown in Figure 4.3. The same MOX feed fuel assembly design as employed in the equilibrium cycle, full MOX core is again used. The CRP is obtained utilizing FORMOSA-B's CRP search capability with core flow adjusted to achieve the target k_{eff} . As before, the target k_{eff} is kept at 1.000 throughout the cycle depletion. Thermal margin and core flow values summarized in Table 6.1 show that a feasible LP/CRP has been obtained. This core will be referred to as the scenario 1 mixed MOX-LEU core whose LP and CRP are shown in Figure 6.2 and Figure 6.3, respectively.

TABLE 6.1: Scenario 1 Mixed MOX-LEU Core's Key Attributes

Cycle Exposure (GWd/ST)	% Rated Core Flow	MFLPD	MAPRAT	MFLCPR	Max. LHGR kw/ft.	MCPR	k_{eff} (ARO, 100% Core Flow)
0	83.402	0.940	0.864	0.926	12.183	1.500	1.0191
1.5	83.113	0.888	0.830	0.907	11.506	1.533	1.0208
3.0	85.040	0.822	0.794	0.911	10.654	1.525	1.0166
4.5	84.736	0.902	0.911	0.933	11.692	1.490	1.0135
6.0	82.999	0.866	0.853	0.910	11.218	1.527	1.0121
7.5	93.177	0.910	0.875	0.938	11.790	1.481	1.0118
9.0	84.096	0.939	0.902	0.942	12.173	1.476	1.0106
10.5	87.805	0.905	0.796	0.894	11.734	1.554	1.0069
11.5	95.541	0.834	0.819	0.880	10.812	1.579	1.0027
12.35	104.665	0.834	0.853	0.878	10.803	1.583	0.9981

		First Index															
		16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
S e c o n d I n d e x	16	2	1	1	1	1	1	1	2	F	2	F	2	F	1	F	2
	15	1	F	2	F	2	F	2	F	2	F	2	F	2	F	1	3
	14	1	2	1	1	1	1	1	1	F	1	F	1	F	2	2	
	13	1	F	1	F	2	F	2	F	2	F	2	F	2	1	2	
	12	1	2	1	2	1	1	1	1	F	1	F	1	F	1	2	
	11	1	F	1	F	1	F	2	F	2	F	2	F	2	1	2	
	10	1	2	1	2	1	2	F	1	F	1	F	1	F	1	2	
	9	2	F	1	F	1	F	1	F	2	F	2	F	1	2		
	8	F	2	F	2	F	2	F	2	F	1	F	1	2			
	7	2	F	1	F	1	F	1	F	1	F	2	1	2			
	6	F	2	F	2	F	2	F	2	F	2	F	1	2			
	5	2	F	1	F	1	F	1	F	1	1	1	2				
	4	F	2	F	2	F	2	F	1	2	2	2					
	3	1	F	2	1	1	1	1	2								
	2	F	1	2	2	2	2	2									
	1	2	3														

The numbers represent the number of previous cycles the bundle has been in the core.

F = MOX Fresh Assemblies

FIGURE 6.2. Scenario 1 Mixed MOX-LEU Core Loading Pattern

FIGURE 6.3. Scenario 1 Mixed MOX-LEU Core Control Rod Patterns

6.2 Transition Back to Full MOX Core

6.2.1 Scenario 1b Mixed MOX-LEU Core

The scenario 1b mixed MOX-LEU core is obtained by loading MOX feed assemblies in the subsequent cycle of the scenario 1 mixed MOX-LEU core. In the scenario 1b mixed MOX-LEU core, there are 8 thrice-burned MOX assemblies, 264 twice-burned LEU assemblies, 264 once-burned MOX assemblies, and 264 fresh MOX assemblies. The CRP for this core is shown in Figure 6.4. A summary of thermal margin and core flow values are shown in Table 6.2. Acceptable thermal margin values are observed. It is noted that the EOC core flow is higher than the specified limit of 105%. Recall that the LP for this core is obtained using the shuffle instructions employed by the equilibrium cycle, full MOX core without any further LP optimization. Currently, employing the FORMOSA-B's LP search capability requires a substantial amount of computational time, hence the desire to avoid the need to complete LP optimization.

TABLE 6.2: Scenario 1b Mixed MOX-LEU Core's Key Attributes

Cycle Exposure (GWd/ST)	% Rated Core Flow	MFLPD	MAPRAT	MFLCPR	Max. LHGR kw/ft.	MCPR	k_{eff} (ARO, 100% Core Flow)
0	85.300	0.935	0.863	0.898	12.118	1.548	1.0185
1.5	85.555	0.875	0.812	0.892	11.343	1.558	1.0205
3.0	89.292	0.895	0.879	0.936	11.597	1.485	1.0166
4.5	85.981	0.921	0.884	0.919	11.941	1.512	1.0139
6.0	80.698	0.950	0.883	0.949	12.305	1.465	1.0127
7.5	89.626	0.928	0.871	0.952	12.029	1.460	1.0127
9.0	85.484	0.864	0.854	0.951	11.192	1.462	1.0114
10.5	89.108	0.889	0.807	0.897	11.518	1.550	1.0068
11.5	97.499	0.860	0.811	0.870	11.146	1.598	1.0017
12.35	108.259	0.828	0.858	0.865	10.728	1.607	0.9966

FIGURE 6.4. Scenario 1b Mixed MOX-LEU Core Control Rod Patterns

Performing LP/CRP search on the scenario 1b mixed MOX-LEU core removes the EOC core flow violation and also reduces the maximum thermal margin values, as shown in Table 6.3. The objective function employed during the Optimization by Simulated Annealing (OSA) cooling cycle is cycle length maximization. The OSA search type is a local search with 2,000 histories and a k_{inf} range of 0.18. The k_{inf} range allows the exchange between once- and twice-burned assemblies. The locations of fresh MOX assemblies are preserved during OSA. A CRP search is performed every 200 histories. The optimized LP and CRP are shown in Figure 6.5 and Figure 6.6, respectively.

TABLE 6.3: Scenario 1b (Optimized) Mixed MOX-LEU Core's Key Attributes

Cycle Exposure (GWd/ST)	% Rated Core Flow	MFLPD	MAPRAT	MFLCPR	Max. LHGR kw/ft.	MCPR	k_{eff} (ARO, 100% Core Flow)
0	85.604	0.863	0.852	0.901	11.188	1.542	1.0171
1.5	86.077	0.927	0.808	0.852	12.013	1.631	1.0193
3.0	86.224	0.933	0.844	0.884	12.097	1.573	1.0159
4.5	85.547	0.874	0.795	0.898	11.330	1.547	1.0134
6.0	85.078	0.920	0.803	0.917	11.919	1.516	1.0123
7.5	87.627	0.867	0.788	0.915	11.232	1.520	1.0125
9.0	96.032	0.901	0.841	0.908	11.677	1.531	1.0118
10.5	89.059	0.885	0.797	0.916	11.465	1.518	1.0083
11.5	94.142	0.840	0.816	0.907	10.884	1.532	1.0041
12.35	103.539	0.863	0.852	0.901	11.188	1.542	0.9994

		First Index															
		16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
S e c o n d I n d e x	16	2	1	1	1	1	2	1	2	F	2	F	2	F	1	F	2
	15	2	F	1	F	2	F	2	F	2	F	1	F	1	F	1	2
	14	1	2	1	1	1	2	1	1	F	1	F	2	F	1	2	
	13	1	F	1	F	2	F	2	F	2	F	2	F	1	1	2	
	12	1	2	1	2	1	2	1	2	F	2	F	1	F	2	2	
	11	1	F	2	F	1	F	2	F	2	F	1	F	1	1	2	
	10	1	2	1	1	1	2	F	1	F	1	F	1	F	2	2	
	9	2	F	1	F	1	F	1	F	1	F	2	F	2	1		
	8	F	2	F	1	F	2	F	1	F	2	F	1	2			
	7	2	F	1	F	1	F	2	F	1	F	2	1	3			
	6	F	2	F	1	F	1	F	2	F	1	F	1	2			
	5	1	F	1	F	2	F	1	F	1	2	1	3				
	4	F	2	F	1	F	1	F	1	2	2	2					
	3	1	F	2	1	2	1	2	2								
	2	F	1	2	2	2	2	2									
	1	2	2														

The numbers represent the number of previous cycles the bundle has been in the core.

F = MOX Fresh Assemblies

FIGURE 6.5. Scenario 1b (Optimized) Mixed MOX-LEU Core Loading Pattern

FIGURE 6.6. Scenario 1b (Optimized) Mixed MOX-LEU Core Control Rod Patterns

26.44	15.05	13.97	15.41	13.86	15.64	13.51	27.19	0.00	28.94	0.00	27.38	0.00	15.47	0.00	27.91
15.31	0.00	28.75	0.00	27.28	0.00	27.99	0.00	29.94	0.00	26.55	0.00	23.56	0.00	11.26	30.19
13.69	29.43	13.51	15.52	12.92	15.59	12.98	15.18	0.00	15.11	0.00	14.31	0.00	21.51	27.79	
14.93	0.00	15.22	0.00	26.16	0.00	28.81	0.00	28.65	0.00	25.05	0.00	24.05	14.33	31.08	
13.54	27.37	12.70	27.46	10.88	15.74	12.67	15.14	0.00	15.15	0.00	14.69	0.00	14.36	31.58	
14.52	0.00	14.90	0.00	15.10	0.00	29.05	0.00	29.77	0.00	25.18	0.00	21.18	14.07	28.27	
13.43	28.62	12.68	29.29	12.48	27.92	0.00	15.13	0.00	15.51	0.00	15.51	0.00	11.52	28.23	
27.59	0.00	14.16	0.00	14.14	0.00	14.62	0.00	24.01	0.00	23.20	0.00	12.58	28.48		
0.00	27.82	0.00	29.11	0.00	30.06	0.00	26.07	0.00	14.37	0.00	15.04	28.37			
27.99	0.00	15.03	0.00	14.72	0.00	13.53	0.00	14.02	0.00	19.01	13.57	27.80			
0.00	26.70	0.00	25.18	0.00	25.67	0.00	24.09	0.00	19.25	0.00	8.95	28.83			
27.45	0.00	13.98	0.00	14.50	0.00	15.02	0.00	15.50	14.24	8.82	26.61				
0.00	24.76	0.00	24.31	0.00	21.46	0.00	12.47	29.18	27.93	28.97					
15.34	0.00	21.84	13.93	15.56	13.71	11.39	28.03								
0.00	11.05	29.20	30.86	27.62	28.22	29.09									
28.07	30.11														

FIGURE 6.7. Scenario 1b Mixed MOX-LEU Core 2D BOC Exposure Map

24.76	11.39	13.98	13.43	13.71	28.62	14.24	27.59	0.00	27.92	0.00	21.46	0.00	12.98	0.00	23.20
27.46	0.00	15.04	0.00	26.07	0.00	27.82	0.00	28.81	0.00	15.05	0.00	15.56	0.00	14.50	29.20
13.69	26.70	13.54	12.48	12.92	23.56	14.93	15.50	0.00	11.05	0.00	21.18	0.00	15.03	26.55	
15.52	0.00	14.16	0.00	27.19	0.00	27.91	0.00	27.45	0.00	26.16	0.00	15.41	15.18	27.79	
15.34	29.77	13.93	27.37	15.74	26.44	14.69	27.99	0.00	24.01	0.00	12.68	0.00	29.29	28.22	
13.57	0.00	28.23	0.00	10.88	0.00	27.62	0.00	27.28	0.00	12.47	0.00	13.51	19.01	27.38	
15.59	28.07	14.72	14.36	14.31	25.18	0.00	13.53	0.00	13.51	0.00	13.86	0.00	25.18	30.86	
27.80	0.00	15.15	0.00	15.64	0.00	15.31	0.00	14.52	0.00	28.97	0.00	25.67	15.51		
0.00	28.37	0.00	15.22	0.00	28.03	0.00	15.11	0.00	29.05	0.00	12.67	28.83			
26.61	0.00	14.62	0.00	14.02	0.00	25.05	0.00	14.37	0.00	19.25	13.97	30.11			
0.00	27.93	0.00	15.51	0.00	14.90	0.00	29.94	0.00	8.82	0.00	12.58	29.09			
15.47	0.00	8.95	0.00	28.75	0.00	11.26	0.00	14.14	28.94	15.13	30.19				
0.00	28.65	0.00	11.52	0.00	12.70	0.00	15.14	28.27	31.58	29.43					
14.07	0.00	21.51	14.33	24.05	15.02	24.31	28.48								
0.00	15.10	29.18	29.11	31.08	30.06	24.09									
21.84	27.99														

FIGURE 6.8. Scenario 1b (Optimized) Mixed MOX-LEU Core 2D BOC Exposure Map

6.2.2 Nearly Full MOX Core

The core obtained by continuing the scenario 1b mixed MOX-LEU core and assuming MOX feed assemblies to be available is referred to as the nearly full MOX core. The core contains eight thrice-burned LEU assemblies, with the rest of the burned assemblies being MOX assemblies. As before, the LP is obtained by using the shuffle instructions employed in the equilibrium cycle, full MOX core (Figure 4.3) and the CRP is obtained using FORMOSA-B's CRP search capability. Figure 6.9 shows the resulting CRP. The nearly full MOX core has acceptable thermal margin and core flow values as shown in Table 6.4.

TABLE 6.4: Nearly Full MOX Core's Key Attributes

Cycle Exposure (GWd/ST)	% Rated Core Flow	MFLPD	MAPRAT	MFLCPR	Max. LHGR kw/ft.	MCPR	k_{eff} (ARO, 100% Core Flow)
0	85.298	0.928	0.853	0.916	12.023	1.517	1.0185
1.5	85.619	0.892	0.789	0.888	11.555	1.565	1.0199
3.0	86.403	0.930	0.835	0.903	12.058	1.538	1.0163
4.5	85.313	0.795	0.793	0.904	10.298	1.538	1.0137
6.0	94.572	0.927	0.885	0.873	12.014	1.592	1.0125
7.5	91.324	0.918	0.879	0.930	11.897	1.494	1.0126
9.0	86.433	0.862	0.861	0.931	11.176	1.492	1.0120
10.5	88.193	0.908	0.799	0.881	11.773	1.578	1.0085
11.5	95.648	0.887	0.799	0.856	11.500	1.623	1.0042
12.35	105.163	0.821	0.820	0.845	10.635	1.644	0.9995

FIGURE 6.9. Nearly Full MOX Core Control Rod Patterns

6.2.3 Full MOX Core

Continuing from the nearly full MOX core and assuming MOX feed assemblies continue to be available results in a full MOX core. The CRP is shown in Figure 6.10. Thermal margin and core flow values are judged to be acceptable (Table 6.5).

TABLE 6.5: Full MOX Core's Key Attributes

Cycle Exposure (GWd/ST)	% Rated Core Flow	MFLPD	MAPRAT	MFLCPR	Max. LHGR kw/ft.	MCPR	k_{eff} (ARO, 100% Core Flow)
0	85.298	0.933	0.862	0.908	12.090	1.530	1.0185
1.5	84.761	0.873	0.805	0.887	11.315	1.567	1.0200
3.0	85.104	0.901	0.812	0.905	11.681	1.536	1.0164
4.5	85.316	0.805	0.784	0.905	10.437	1.536	1.0137
6.0	92.666	0.938	0.902	0.872	12.156	1.593	1.0125
7.5	91.649	0.914	0.860	0.924	11.846	1.504	1.0125
9.0	85.030	0.918	0.917	0.930	11.902	1.494	1.0118
10.5	87.180	0.902	0.800	0.885	11.689	1.570	1.0083
11.5	94.307	0.872	0.805	0.864	11.296	1.609	1.0042
12.35	103.429	0.802	0.829	0.855	10.401	1.626	0.9997

6.3 Summary of Disruption Scenario 1 Cores

We conclude that we have successfully established a disruption scenario in which the mixed MOX-LEU core is introduced by loading LEU fresh assemblies into the initial mixed core, and a full MOX core is produced by assuming the complete availability of the MOX fresh assemblies for subsequent cycles following the initial mixed MOX-LEU core. The MOX feed assemblies' mean enrichments (Table 6.6) are constant, since only one

MOX fuel bundle design was utilized throughout this study. Figure 6.11 through Figure 6.17 summarizes disruption scenario 1 cores' key properties.

FIGURE 6.10. Full MOX Core Control Rod Patterns

TABLE 6.6: Summary of Feed Assemblies' Mean Enrichment for Disruption Scenario 1 Cores

Core	Mean Enrichment
Equilibrium Cycle, Full MOX Core	4.310w/o WGPu
Initial Mixed MOX-LEU Core	3.847 w/o U-235
Scenario 1 Mixed MOX-LEU Core	4.310w/o WGPu
Scenario 1b Mixed MOX-LEU Core	4.310w/o WGPu
Nearly Full MOX Core	4.310w/o WGPu
Full MOX Core	4.310w/o WGPu

FIGURE 6.11. Summary of Rated Core Flow for Disruption Scenario 1 Cores

FIGURE 6.12. Summary of MFLPD for Disruption Scenario 1 Cores

FIGURE 6.13. Summary of MAPRAT for Disruption Scenario 1 Cores

FIGURE 6.14. Summary of MFLCPR for Disruption Scenario 1 Cores

FIGURE 6.15. Summary of Maximum LHGR for Disruption Scenario 1 Cores

FIGURE 6.16. Summary of MCPR for Disruption Scenario 1 Cores

FIGURE 6.17. Summary of k_{eff} (ARO, 100% Flow) for Disruption Scenario 1 Cores

6.4 Scenario 2: MOX Feed Batches Continue to be Unavailable for Subsequent Cycle

Similar to the approach used in developing the initial mixed MOX-LEU core, the subsequent cycle's loading pattern is determined using the equilibrium cycle, full MOX core's shuffling instruction shown in Figure 4.3. Two enrichment types of LEU fresh assemblies (Figure 5.7 and Figure 5.8) are employed. The mix of LEU enrichment 2 and 3 is determined such that the cycle energy requirement is met. The CRP for the core is determined utilizing FORMOSA-B's CRP search capability with the core flow adjusted to meet the target k_{eff} . Again, the target k_{eff} is kept at 1.000 throughout the cycle depletion. The core in which the second region of LEU feed assemblies is loaded will be referred to as the scenario 2 mixed MOX-LEU core.

The CRP and LP for the resulting scenario 2 mixed MOX-LEU core are shown in Figure 6.18 and Figure 6.19, respectively. The LEU feed assemblies' mean enrichment for the scenario 2 mixed MOX-LEU core is higher than the mean enrichment required in the initial mixed MOX-LEU core. This occurs since lattice reactivity decreases faster with burnup for LEU versus MOX lattices. The core's key attributes are summarized in Table 6.7. Thermal limits and EOC core flow required to achieve criticality for the scenario 2 mixed MOX-LEU core are comparable to the values obtained for the equilibrium cycle, full MOX and the initial mixed MOX-LEU cores. It is noted that a slightly higher cycle maximum MFLCPR (0.963) value exists. Performing a FORMOSA-B LP/CRP search (2,000 histories of OSA local search with a k_{inf} range of 0.18 and OSA objective of cycle length maximization) lowers the cycle maximum MFLCPR value to an acceptable 0.948 (Table 6.8).

TABLE 6.7: Scenario 2 Mixed MOX-LEU Core's Key Attributes

Cycle Exposure (GWd/ST)	% Rated Core Flow	MFLPD	MAPRAT	MFLCPR	Max. LHGR kw/ft.	MCPR	k _{eff} (ARO, 100% Core Flow)
0	84.098	0.932	0.833	0.916	12.085	1.518	1.0253
1.5	82.181	0.935	0.863	0.956	12.124	1.455	1.0314
3.0	83.019	0.909	0.817	0.934	11.777	1.488	1.0291
4.5	88.442	0.908	0.879	0.934	11.771	1.488	1.0274
6.0	90.677	0.921	0.850	0.915	11.933	1.520	1.0267
7.5	88.293	0.886	0.913	0.963	11.489	1.444	1.0263
9.0	84.305	0.826	0.843	0.961	10.709	1.440	1.0235
10.5	85.683	0.808	0.776	0.907	10.478	1.532	1.0164
11.5	93.641	0.819	0.785	0.862	10.620	1.613	1.0098
12.35	105.422	0.802	0.829	0.855	10.401	1.626	0.9997

TABLE 6.8: Scenario 2 (Optimized) Mixed MOX-LEU Core's Key Attributes

Cycle Exposure (GWd/ST)	% Rated Core Flow	MFLPD	MAPRAT	MFLCPR	Max. LHGR kw/ft.	MCPR	k _{eff} (ARO, 100% Core Flow)
0	85.440	0.935	0.830	0.916	12.119	1.517	1.0239
1.5	92.412	0.895	0.839	0.903	11.602	1.539	1.0300
3.0	88.754	0.905	0.823	0.911	11.723	1.526	1.0278
4.5	96.814	0.838	0.795	0.938	10.858	1.482	1.0261
6.0	87.195	0.832	0.837	0.920	10.784	1.511	1.0253
7.5	91.643	0.864	0.907	0.944	11.198	1.472	1.0250
9.0	86.138	0.815	0.826	0.948	10.557	1.466	1.0225
10.5	84.782	0.824	0.786	0.911	10.678	1.525	1.0159
11.5	92.733	0.794	0.781	0.877	10.290	1.585	1.0095
12.35	103.452	0.761	0.772	0.851	9.858	1.634	1.0033

TABLE 6.9: Nearly Full LEU Core's Key Attributes

Cycle Exposure (GWd/ST)	% Rated Core Flow	MFLPD	MAPRAT	MFLCPR	Max. LHGR kw/ft.	MCPR	k _{eff} (ARO, 100% Core Flow)
0	84.098	0.934	0.830	0.905	12.104	1.536	1.0274
1.5	86.287	0.920	0.822	0.949	11.919	1.464	1.0337
3.0	84.651	0.884	0.858	0.951	11.453	1.462	1.0311
4.5	90.370	0.872	0.856	0.925	11.297	1.502	1.0289
6.0	86.459	0.923	0.923	0.952	11.963	1.460	1.0277
7.5	89.664	0.906	0.898	0.950	11.736	1.463	1.0269
9.0	85.835	0.842	0.858	0.956	10.909	1.454	1.0239
10.5	84.999	0.844	0.803	0.923	10.932	1.506	1.0169
11.5	93.160	0.853	0.832	0.880	11.061	1.580	1.0102
12.35	104.774	0.826	0.811	0.845	10.706	1.645	1.0037

TABLE 6.10: Full LEU Core's Key Attributes

Cycle Exposure (GWd/ST)	% Rated Core Flow	MFLPD	MAPRAT	MFLCPR	Max. LHGR kw/ft.	MCPR	k _{eff} (ARO, 100% Core Flow)
0	85.245	0.936	0.831	0.912	12.127	1.524	1.0267
1.5	85.089	0.922	0.851	0.921	11.945	1.508	1.0331
3.0	85.980	0.906	0.815	0.927	11.748	1.499	1.0307
4.5	91.279	0.832	0.810	0.940	10.786	1.479	1.0287
6.0	86.230	0.803	0.762	0.928	10.411	1.497	1.0277
7.5	91.349	0.882	0.853	0.939	11.433	1.481	1.0270
9.0	92.772	0.793	0.794	0.939	10.281	1.480	1.0239
10.5	84.996	0.827	0.802	0.931	10.714	1.492	1.0164
11.5	92.678	0.830	0.807	0.883	10.756	1.574	1.0095
12.35	103.704	0.793	0.767	0.855	10.282	1.626	1.0029

		First Index															
		16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
S e c o n d I n d e x	16	2	1	1	1	1	2	1	2	F3	2	F3	2	F3	1	F3	2
	15	2	F2	1	F2	2	F2	2	F3	2	F3	1	F3	1	F3	1	2
	14	1	2	1	1	1	2	1	1	F2	1	F3	2	F3	1	2	
	13	1	F2	1	F3	2	F3	2	F3	2	F3	2	F3	1	1	2	
	12	1	2	1	2	1	2	1	2	F3	2	F3	1	F2	2	2	
	11	1	F2	2	F3	1	F3	2	F3	2	F3	1	F3	1	1	2	
	10	1	2	1	1	1	2	F3	1	F3	1	F3	1	F2	2	2	
	9	2	F3	1	F3	1	F3	1	F3	1	F2	2	F2	2	1		
	8	F3	2	F2	1	F3	2	F3	1	F3	2	F2	1	2			
	7	2	F3	1	F3	1	F3	2	F2	1	F3	2	1	3			
	6	F3	2	F3	1	F3	1	F3	2	F2	1	F2	1	2			
	5	1	F3	1	F3	2	F3	1	F2	1	2	1	3				
	4	F3	2	F3	1	F2	1	F2	1	2	2	2					
	3	1	F3	2	1	2	1	2	2								
	2	F3	1	2	2	2	2	2									
	1	2	2														

The numbers represent the number of previous cycles the bundle has been in the core. The symbol F denotes fresh fuels.

F2 = LEU Enrichment 2 (Figure 5.7)

F3 = LEU Enrichment 3 (Figure 5.8)

FIGURE 6.18. Scenario 2 Mixed MOX-LEU Core Loading Pattern

FIGURE 6.19. Scenario 2 Mixed MOX-LEU Core Control Rod Patterns

FIGURE 6.20. Scenario 2 (Optimized) Mixed MOX-LEU Core Control Rod Patterns

24.10	14.14	14.80	13.29	15.43	13.81	14.91	28.27	0.00	29.64	0.00	27.75	0.00	13.80	0.00	28.87
14.29	0.00	28.60	0.00	27.85	0.00	26.50	0.00	27.06	0.00	26.74	0.00	24.30	0.00	12.26	30.48
15.36	29.03	13.25	14.68	13.96	13.00	13.26	16.31	0.00	16.17	0.00	13.67	0.00	20.82	28.62	
13.75	0.00	15.68	0.00	28.95	0.00	26.52	0.00	27.41	0.00	27.18	0.00	23.30	14.72	28.46	
13.57	28.48	14.36	29.32	12.26	13.19	13.61	14.14	0.00	13.76	0.00	15.02	0.00	13.88	27.94	
14.53	0.00	13.53	0.00	14.89	0.00	26.28	0.00	27.48	0.00	25.20	0.00	20.75	13.71	28.81	
15.11	27.32	14.28	26.82	14.09	26.25	0.00	13.98	0.00	13.71	0.00	13.19	0.00	12.60	29.39	
28.36	0.00	13.10	0.00	14.87	0.00	14.53	0.00	24.27	0.00	24.39	0.00	13.75	28.82		
0.00	27.02	0.00	27.39	0.00	27.20	0.00	26.22	0.00	14.64	0.00	15.28	29.68			
29.61	0.00	16.48	0.00	14.20	0.00	13.75	0.00	13.67	0.00	18.47	13.50	28.42			
0.00	27.70	0.00	27.71	0.00	25.34	0.00	24.50	0.00	18.41	0.00	10.10	28.12			
28.65	0.00	14.15	0.00	16.01	0.00	14.76	0.00	15.49	14.78	10.35	26.68				
0.00	24.98	0.00	23.65	0.00	20.89	0.00	14.16	28.39	28.56	27.55					
14.14	0.00	21.09	15.33	16.00	14.61	12.98	29.29								
0.00	12.69	29.37	29.08	27.72	28.67	29.11									
28.55	30.43														

FIGURE 6.21. Scenario 2 Mixed MOX-LEU Core 2D BOC Exposure Map

13.75	27.75	14.09	14.80	13.61	13.10	24.50	28.65	0.00	29.11	0.00	28.36	0.00	13.81	0.00	14.29
27.18	0.00	14.14	0.00	13.29	0.00	27.71	0.00	26.25	0.00	26.28	0.00	27.70	0.00	12.26	29.61
20.75	28.48	13.00	24.30	16.17	15.43	13.80	14.76	0.00	14.87	0.00	13.19	0.00	28.55	24.39	
14.78	0.00	16.01	0.00	28.42	0.00	29.39	0.00	14.61	0.00	27.94	0.00	15.49	26.82	29.08	
27.20	13.75	15.68	29.03	14.53	14.89	20.82	26.52	0.00	18.41	0.00	27.39	0.00	15.36	30.48	
10.35	0.00	13.26	0.00	15.02	0.00	27.41	0.00	25.20	0.00	28.62	0.00	15.33	24.10	20.89	
14.68	28.95	13.71	14.14	13.57	15.28	0.00	24.27	0.00	14.36	0.00	14.16	0.00	12.69	16.00	
28.12	0.00	14.15	0.00	13.96	0.00	28.46	0.00	16.48	0.00	13.98	0.00	12.26	28.87		
0.00	24.98	0.00	28.60	0.00	26.22	0.00	27.55	0.00	13.25	0.00	14.53	29.64			
27.85	0.00	13.50	0.00	27.48	0.00	14.20	0.00	13.88	0.00	14.64	14.91	29.32			
0.00	27.02	0.00	27.06	0.00	26.68	0.00	13.67	0.00	28.27	0.00	14.28	25.34			
28.82	0.00	21.09	0.00	13.19	0.00	13.53	0.00	16.31	10.10	23.65	28.81				
0.00	14.72	0.00	12.98	0.00	13.67	0.00	13.75	28.39	18.47	29.37					
23.30	0.00	13.71	13.76	26.74	14.14	15.11	27.72								
0.00	12.60	28.56	28.67	26.50	27.32	29.68									
29.29	30.43														

FIGURE 6.22. Scenario 2 (Optimized) Mixed MOX-LEU Core 2D BOC Exposure Map

6.5 Transition Back to Full LEU Core

6.5.1 Nearly Full LEU Core

Continuing from the scenario 2 mixed MOX-LEU core, which assumes that MOX assemblies are unavailable, another mixed MOX-LEU core is produced. This core is referred to as the nearly full LEU core since only eight out of 800 assemblies are MOX assemblies. The LP and CRP are shown in Figure 6.23 and Figure 6.24, respectively. A summary of thermal margin and core flow values are shown in Figure 6.9.

6.5.2 Full LEU Core

A full LEU core is obtained by continuing the nearly full LEU core and loading another region of LEU fresh fuel assemblies into the core. The LP and CRP are shown in Figure 6.25 and Figure 6.26. Thermal margin and core flow values are judged to be acceptable (Table 6.10).

		First Index															
		16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
S e c o n d I n d e x	16	2	1	1	1	1	2	1	2	F3	2	F3	2	F3	1	F3	2
	15	2	F2	1	F2	2	F2	2	F3	2	F3	1	F3	1	F3	1	2
	14	1	2	1	1	1	2	1	1	F3	1	F3	2	F3	1	2	
	13	1	F2	1	F3	2	F3	2	F3	2	F3	2	F3	1	1	2	
	12	1	2	1	2	1	2	1	2	F3	2	F3	1	F2	2	2	
	11	1	F2	2	F3	1	F3	2	F3	2	F3	1	F3	1	1	2	
	10	1	2	1	1	1	2	F3	1	F3	1	F3	1	F2	2	2	
	9	2	F3	1	F3	1	F3	1	F3	1	F2	2	F2	2	1		
	8	F3	2	F3	1	F3	2	F3	1	F3	2	F2	1	2			
	7	2	F3	1	F3	1	F3	2	F2	1	F3	2	1	3			
	6	F3	2	F3	1	F3	1	F3	2	F2	1	F2	1	2			
	5	1	F3	1	F3	2	F3	1	F2	1	2	1	3				
	4	F3	2	F3	1	F2	1	F2	1	2	2	2					
	3	1	F3	2	1	2	1	2	2								
	2	F3	1	2	2	2	2	2									
	1	2	2														

The numbers represent the number of previous cycles the bundle has been in the core. The symbol F denotes fresh fuels.

F2 = LEU Enrichment 2 (Figure 5.7)

F3 = LEU Enrichment 3 (Figure 5.8)

FIGURE 6.23. Nearly Full LEU Core Loading Pattern

FIGURE 6.24. Nearly Full LEU Core Control Rod Patterns

		First Index															
		16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
S e c o n d I n d e x	16	2	1	1	1	1	2	1	2	F3	2	F3	2	F3	1	F3	2
	15	2	F2	1	F2	2	F2	2	F3	2	F3	1	F3	1	F3	1	2
	14	1	2	1	1	1	2	1	1	F3	1	F3	2	F3	1	2	
	13	1	F2	1	F3	2	F3	2	F3	2	F3	2	F3	1	1	2	
	12	1	2	1	2	1	2	1	2	F3	2	F3	1	F2	2	2	
	11	1	F2	2	F3	1	F3	2	F3	2	F3	1	F3	1	1	2	
	10	1	2	1	1	1	2	F3	1	F3	1	F3	1	F2	2	2	
	9	2	F3	1	F3	1	F3	1	F3	1	F2	2	F2	2	1		
	8	F3	2	F3	1	F3	2	F3	1	F3	2	F2	1	2			
	7	2	F3	1	F3	1	F3	2	F2	1	F3	2	1	3			
	6	F3	2	F3	1	F3	1	F3	2	F2	1	F2	1	2			
	5	1	F3	1	F3	2	F3	1	F2	1	2	1	3				
	4	F3	2	F3	1	F2	1	F2	1	2	2	2					
	3	1	F3	2	1	2	1	2	2								
	2	F3	1	2	2	2	2	2									
	1	2	2														

The numbers represent the number of previous cycles the bundle has been in the core. The symbol F denotes fresh fuels.

F2 = LEU Enrichment 2 (Figure 5.7)

F3 = LEU Enrichment 3 (Figure 5.8)

FIGURE 6.25. Full LEU Core Loading Pattern

FIGURE 6.26. Full LEU Core Control Rod Patterns

6.6 Summary of Disruption Scenario 2 Cores

We conclude that we have established the second disruption scenario in which the transitioning from an equilibrium cycle, full MOX core to a full LEU core occurs by assuming complete availability of LEU fresh assemblies for subsequent cycles following the initial mixed MOX-LEU core. A summary of LEU feed assemblies' mean enrichments is shown in Table 6.11. Figure 6.11 through Figure 6.17 summarizes disruption scenario 1 cores' key properties.

TABLE 6.11: Summary of Feed Assemblies' Mean Enrichment for Disruption Scenario 2 Cores

Core	Mean Enrichment
Equilibrium Cycle, Full MOX Core	4.310w/o WGPu
Initial Mixed MOX-LEU Core	3.847 w/o U-235
Scenario 2 Mixed MOX-LEU Core	3.915w/o U-235
Nearly Full LEU Core	3.924 w/o U-235
Full LEU Core	3.870 w/o U-235

FIGURE 6.27. Summary of Rated Core Flow for Disruption Scenario 2 Cores

FIGURE 6.28. Summary of MFLPD for Disruption Scenario 2 Cores

FIGURE 6.29. Summary of MAPRAT for Disruption Scenario 2 Cores

FIGURE 6.30. Summary of MFLCPR for Disruption Scenario 2 Cores

FIGURE 6.31. Summary of Maximum LHGR for Disruption Scenario 2 Cores

FIGURE 6.32. Summary of MCPR for Disruption Scenario 2 Cores

FIGURE 6.33. Summary of k_{eff} (ARO, 100% Core Flow) for Disruption Scenario 2 Cores

7. Conclusions

For the initial mixed LEU-MOX core, starting with the GE equilibrium cycle, full MOX core, an acceptable LP was determined in regard to satisfying all constraints. For the subsequent cycle, the following two disruption scenarios were examined: (1) complete availability of MOX feed assemblies, and (2) complete unavailability of MOX feed assemblies.

The first scenario leads to a full MOX core and the second scenario leads to a full LEU core. Transition cycles from the equilibrium cycle, full MOX core to another full MOX core and from the equilibrium cycle, full MOX core to a full LEU core have been developed. LPs and CRPs found by FORMOSA-B for those transition cycles are judged to be acceptable with regard to the constraints imposed.

8. Acknowledgment

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9. References

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- [2] I. ARIANI and P.J. TURINSKY, "Evaluation of Mixed LEU-MOX Loading Patterns for LWRs Originating from Inability to Deliver MOX Assemblies: Westinghouse Reload Core Study," ORNL/SUB/99-19XSY063V-2, Oak Ridge National Laboratory, February 1999.
- [3] "FMS: The Scanpower Fuel Management System, HELIOS Documentation," Scanpower A/S, 1995.
- [4] "FORCIP-B V1.0 Code Manual: FORMOSA-B Cross Section Interface Program," Electric Power Research Center, North Carolina State University, 1998
- [5] "FORMOSA-B V1.0 User's Manual: Fuel Management Optimization Software for BWRs," Electric Power Research Center, North Carolina State University, 1999
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Appendices

HELIOS, ZENITH, FORCIP-B and FORMOSA-B input and output files for cores examined in this study are available in the /u10/fmdp2/GEBWR.DIR directory. Below is the summary of the contents of the /u10/fmdp2/GEBWR.DIR directory:

HELIOSINPUT.DIR

MOX Lattice:

Lower:

1.lower0.inp	: 0% Void, Unrodded
2.lower40.inp	: 40% Void, Unrodded
3.lower70.inp	: 70% Void, Unrodded
4.lower40CRH.inp	: 40% Void, Rodded

Middle:

5.middle0.inp	: 0% Void, Unrodded
6.middle40.inp	: 40% Void, Unrodded
7.middle70.inp	: 70% Void, Unrodded
8.middle40CRH.inp	: 40% Void, Rodded

Upper:

9.upper0.inp	: 0% Void, Unrodded
10.upper40.inp	: 40% Void, Unrodded
11.upper70.inp	: 70% Void, Unrodded
12.upper40CRH.inp	: 40% Void, Rodded

LEU Enrichment 2 Lattice:

Lower:

13.lleulower00.inp	: 0% Void, Unrodded
14.lleulower40.inp	: 40% Void, Unrodded
15.lleulower70.inp	: 70% Void, Unrodded
16.lleulower40CRH.inp	: 40% Void, Rodded

Middle:

17.lleumiddle0.inp	: 0% Void, Unrodded
18.lleumiddle40.inp	: 40% Void, Unrodded
19.lleumiddle70.inp	: 70% Void, Unrodded
20.lleumiddle40CRH.inp	: 40% Void, Rodded

Upper:

21.lleuupper00.inp	: 0% Void, Unrodded
22.lleuupper40.inp	: 40% Void, Unrodded
23.lleuupper70.inp	: 70% Void, Unrodded
24.lleuupper40CRH.inp	: 40% Void, Rodded

LEU Enrichment 3 Lattice:

Lower:

25.hleulower00.inp : 0% Void, Unrodded
26.hleulower40.inp : 40% Void, Unrodded
27.hleulower70.inp : 70% Void, Unrodded
28.hleulower40CRH.inp: 40% Void, Rodded

Middle:

29.hleumiddle0.inp : 0% Void, Unrodded
30.hleumiddle40.inp : 40% Void, Unrodded
31.hleumiddle70.inp : 70% Void, Unrodded
32.hleumiddle40CRH.inp: 40% Void, Rodded

Upper:

33.hleuupper00.inp : 0% Void, Unrodded
34.hleuupper40.inp : 40% Void, Unrodded
35.hleuupper70.inp : 70% Void, Unrodded
36.hleuupper40CRH.inp: 40% Void, Rodded

ZENITHINPUT.DIR

File names are in a similar format to the HELIOS input file names. Add 'z' at the beginning of each file name. Example: zlower0.inp is the ZENITH input file for MOX lattice (lower, 0% void, unrodded).

Number of files = 36 (37 - 72)

ZENITHOUTPUT.DIR

File names follow the format of filenames for ZENITH input. Replace ".inp" with ".out". Example: zlower0.out is the ZENITH output file for MOX lattice (lower, 0% void, unrodded).

Number of files = 36 (72 - 108)

Cross sections for reflector regions:

109. bwrref.cax
110. rrefcld.cax
111. bwrbrf.cax
112. brefcld.cax
113. bwrtref0.cax
114. bwrtref4.cax
115. bwrtref7.cax
116. trefcld.cax

FORCIPB.DIR

117. forcip.inp : FORCIP-B input file
118. forcipb.table : FORCIP-B output file
119. fcpv1.0.sun. : FORCIP-B executable (SUN)

FORMOSAB.DIR

120. fsbv1.5.sun : FORMOSA-B executable (SUN)
121. basic.data : Basic Operational Data
122. steam.data :
123. spcvmox.dat :

Files in the following subdirectories have the following format:

form.cntl : FORMOSA-B Control File
*.inp : FORMOSA-B Input File
*.cyc : FORMOSA-B Cycle Data File
*out : FORMOSA-B Output File
*aro.inp : FORMOSA-B Input File (ARO, 100% Core Flow)
*arout : FORMOSA-B Output File (ARO, 100% Core Flow)

EQCYCFULLMOX.DIR : Equilibrium Cycle Full MOX Core

124. form.cntl
125. eqcycfullmox.inp
126. eqcycfullmox.cyc
127. eqcycfullmoxout
128. eqcycfullmoxaro.inp
129. eqcycfullmoxarout

INITMIXED.DIR : Initial Mixed MOX-LEU Core

130. form.cntl
131. initmixmoxleu.inp
132. initmixmoxleu.cyc
133. initmixmoxleuout
134. initmixmoxleuaro.inp
135. initmixmoxleuarout

SCENARIO1.DIR : Disruption Scenario1 Cores

136. form.cntl
137. slmix.inp : Scenario 1 Mixed MOX-LEU Core
138. slmix.cyc

139. slmixout
 140. slmixaro.inp
 141. slmixaroot
 142. slbmix.inp: Scenario 1b Mixed MOX-LEU Core
 143. slbmix.cyc
 144. slbmixaro.inp
 145. slbmixaroot
 146. opts1bmix.inp: Optimized LP / CRP
 147. opts1bmixout
 148. opts1bmixaro.inp
 149. opts1bmixaroot
 150. nearlymox.inp
 151. nearlymox.cyc
 152. nearlymoxout
 153. nearlymoxaro.inp
 154. nearlymoxaroot
 155. fullmox.inp
 156. fullmox.cyc
 157. fullmoxout
 158. fullmoxaro.inp
 159. fullmoxaroot

SCENARIO2.DIR : Disruption Scenario2 Cores

136. form.cntl
 137. s2mix.inp : Scenario 2 Mixed MOX-LEU Core
 138. s2mix.cyc
 139. s2mixout
 140. s2mixaro.inp
 141. s2mixaroot
 146. opts2mix.inp: Optimized LP / CRP
 147. opts2mixout
 148. opts2mixaro.inp
 149. opts2mixaroot
 150. nearlyleu.inp
 151. nearlyleu.cyc
 152. nearlyleuout
 153. nearlyleuaro.inp
 154. nearlyleuaroot
 155. fullleu.inp
 156. fullleu.cyc
 157. fullleuout
 158. fullleuaro.inp
 159. fullleuaroot

A1. HELIOS Sample Input File

HELIOS input files for MOX lattices are available in the subdirectories of /u10/fcd/helios_user_dir/XSBWR. The following is a HELIOS input file for one of the LEU lattice designs employed in the mixed MOX-LEU cores. The complete HELIOS/ZENITH input files for LEU lattices are available in /u10/fmdp2/GEBWR.DIR.

HELIOS Input File for Lower LEU Enrichment 2 Lattice

```
+HEL
Lc611      = CASE('library.bin'/'lleulower0.hrf'/'Lower 0%void LEU')
! ===== !
!           Data Bank Generation for an 9x9 BWR Lattice           !
!           MOX Weapons Grade Plutonium Incinerator               !
! ===== !
! ***** !
! START:      Common input for all cases Fmdp GE-11              !
!           March 17,98. See: better grid in CR region with small span !
! ***** !
! ===== !
!           Data Bank Generation for an 9x9 BWR Lattice           !
!           MOX Weapons Grade Plutonium Incinerator               !
! ===== !
&'9x9T'    = SET ('BWR9x9.SET'/ BWR) ! choose R(regular) T(fat corner box) !
&'GE-20'   = SET ('BWR9x9.SET'/ BWR; CR)!choose 17-18-19-20 and 21 absorber pins!
&'TIP-'    = SET ('BWR9x9.SET'/ BWR; Overlays) ! choose tip + or no tip - !
&'Output'  = SET ('BWR9x9.SET'/ BWR; DataBank) ! choose output parameters !
&GE11      = SET ('BWR9x9.SET'/ BWR; Spacers) ! choose spacers:cases 10 to 22 !
! ----- Temperatures, power, from Trent; Feb 3,98 ----- !
!           $tfuel      = PAR ("840") Average Tfuel,K [566.85C] !
!           $tmod = PAR ("558") Tmoderator,K[284.85C,544.7F,1003psia,68.3at,6.92MPa] !
!           $delc      = PAR ("124")           Delta T in clad !
! ----- Temperatures, from NCSU Feb 23,98 ----- !
$tfuel      = PAR ("792.5")!Average Tfuel,K [519.35C] !
$tmod       = PAR ("560")! Tmoderator,K[286.85C,548.3F,1034psia,70.4at,7.13MPa] !
$delc       = PAR ("124")           ! Delta T in clad !
$pow        = PAR ("26.47") ! Power density[W/gU]2266.5days(5cy) up to 60GwD/MT !
! ----- Flow box and gap(from ScandPower model)----- !
!           $bid = PAR ("13.2400") Flow box inner dimension [cm] !
!           $brad = PAR ("0.9500") Flow box inner radius [cm] !
!           $ng= PAR ("0.80000") Half of narrow water gap [cm] !
!           $wg=PAR ("0.80000") Half of wide water gap [cm] !
!           $bwt=PAR ("0.2000") Box thickness (thin box) [cm] !
!           $bct=PAR ("0.3000") Box thickness in corner [cm] !
! ----- Flow box and gap(from NCSU, Feb 23,98)----- !
```

```

$bid      = PAR ("13.40612")           ! Flow box inner dimension [cm] !
$brad     = PAR ("1.0414")             ! Flow box inner radius [cm] !
$ng       = PAR ("0.62738")            ! Half of narrow water gap [cm] !
$wg       = PAR ("0.90170")            ! Half of wide water gap [cm] !
$bwt      = PAR ("0.1524")             ! Box thickness (thin box) [cm] !
$bct      = PAR ("0.2540")             ! Box thickness in corner [cm] !
$rampw    = PAR ("0.120")              ! Ramp width(from 8x8 case)[cm] !
! ----- Fuel and Gd pins ----- !
!                                     $p=PAR ("1.43576") Fuel pin pitch [cm] !
$P        = PAR ("1.43764")            ! Fuel pin pitch NCSU,2-23-98 [cm] !
$rf1      = PAR ("0.47752")            ! Fuel pellet radius real [cm] !
$relr     = PAR ("0.9")! relative radius first fuel region, 2nd is "Pu region"!
$rcir     = PAR ("0.48768")            ! Clad inner radius real [cm] !
$rcil     = PAR ("0.47752")            ! Clad inner radius smear g[cm] !
$rcol     = PAR ("0.55880")            ! Clad outer radius [cm] !
! ----- Water rod ----- !
$rwil     = PAR ("1.16840")            ! Clad inner radius NCSU 2-23-98[cm] !
$rwol     = PAR ("1.24460")            ! Clad outer radius NCSU 2-23-98[cm] !
$xc1      = PAR ("0.18")               ! center water rod [cm] !
$yc1      = PAR (" $xc1 ")             ! center water rod [cm] !
$xc2      = PAR ("-$p-0.18")           ! center water rod [cm] !
$yc2      = PAR ("-$p-0.18")           ! center water rod [cm] !
$rwel     = PAR ("1.25")               ! External radius water around !

! ----- Detector ----- !
$RiTip    = PAR ("0.3000")             ! Inner TIP tube radius [cm] !
$RoTip    = PAR ("0.5000")             ! Outer TIP tube radius [cm] !
$RiInst   = PAR ("0.7000")             ! Inner instrument tube radius !
$RoInst   = PAR ("0.8000")             ! Outer instrument tube radius !

! ----- Control rod(Scandpower Model)----- !
!                                     { $CRrcl=PAR ("0.5500/2") Absorber clad radius [cm] !
!                                     { $CRrab=PAR ("0.2500") Absorber B4C radius [cm] !
! 0.045 cm water gap <<<{ $CRwsp=PAR ("12.500") Control blade wing span [cm] !
!                                     { $CRcsp= PAR("2.0000") Centre piece half span [cm] !
!                                     { $CRth=PAR("0.8400/2") Control blade half thickness !
!                                     { $CRshr=PAR("0.1000")shroud thickness [cm] !
! ----- Control rod(Data from NCSU, March 11.98 ----- !
$CRrcl    = PAR ("0.2003")             ! Absorber clad radius 0.025cm thick [cm] !
$CRrab    = PAR ("0.1753")             ! Absorber B4C radius [cm] !
$CRwsp    = PAR ("10.4555") !wing span[cm]=9.009(ACT)+0.1346(NONAct) (NCSU) !
!                                     +0.42(half thick) !
$CRcsp    = PAR ("0.5546") !Centre piece half span[cm]=0.1346(Nonact)+0.42 !
$CRth     = PAR ("0.3453") !Control blade half thickness>> 0.045cm H2O gap !
$CRshr    = PAR ("0.1000")             ! Shroud thickness [cm] !

! ----- Spacer ----- !
$NrFpin1  = PAR ("66")                 ! Nr of fuel/gad pins w/ $rcol !
$NrWpin1  = PAR ("2")                  ! Nr of water pins w/ $rwol !
$hnode    = PAR ("15.24")              ! Height of one axial node [cm] !
$WtSpIn   = PAR ("50.0")               ! Spacer weight (Inconel) [g] !
$WtSpZr   = PAR ("250.0")              ! Spacer weight (Zircaloy) [g] !
$RhoSpIn  = PAR ("8.20")               ! Density of Inc spacer [g/cm3] !
$RhoSpZr  = PAR ("6.55")               ! Density of Zr spacer [g/cm3] !

! ----- Coolant materials ----- !
$Rho1     = PAR ("0.7441")             ! 560K, 0% steam void [g/cm3] !
$Rho2     = PAR ("0.4614")             ! 560K, 40% steam void [g/cm3] !
$Rho3     = PAR ("0.2494")             ! 560K, 70% steam void [g/cm3] !

```

```

$Rhoc      = PAR ("0.9983")                ! 293K, 0% steam void [g/cm3] !
'H2O-v1'   = MAT ($Rho1 / 1001, 11.19; 8016,88.81)      ! Hot, 1st void !
'H2O-v2'   = MAT ($Rho2 / 1001, 11.19; 8016,88.81)      ! Hot, 2nd void !
'H2O-v3'   = MAT ($Rho3 / 1001, 11.19; 8016,88.81)      ! Hot, 3rd void !
'H2O-c'    = MAT ($Rhoc / 1001, 11.19; 8016,88.81)      ! Cold, no void !
! ----- Fuel materials ----- !
! Pu/Am fraction from Trent. Add to 0.9974, ie 0.26% unaccounted (is it Ga? ) !
! Pu Fissile isotopic: 92.25 w% (w/respect to Pu+Am + Missing !
!           92.49 w% (w/respect to Pu+Am !
!           93.33 w% (w/respect to Pu !
!           $a8= PAR(" 0.0003 ") Pu-238 fraction of 90 % fissile Pu !
!           $a9= PAR(" 0.9220 ") Pu-239 fraction of 90 % fissile Pu !
!           $a0= PAR(" 0.0646 ") Pu-240 fraction of 90 % fissile Pu !
!           $a1= PAR(" 0.0005 ") Pu-241 fraction of 90 % fissile Pu !
!           $a2= PAR(" 0.0010 ") Pu-242 fraction of 90 % fissile Pu !
!           $Am1= PAR(" 0.0090 ") Am-241 fraction of 90 % fissile Pu !
! Pu/Am fraction from GE report it add 1.000 !
! Pu Fissile isotopic: 94.00 w% (w/respect to Pu+Am !
!           94.28 w% (w/respect to Pu !
$a8= PAR(" 0.000 ") ! Pu-238 fraction weapon grade Pu !
$a9= PAR(" 0.9370 ") ! Pu-239 fraction weapon grade Pu !
$a0= PAR(" 0.0570 ") ! Pu-240 fraction weapon grade Pu !
$a1= PAR(" 0.0030 ") ! Pu-241 fraction weapon grade Pu !
$a2= PAR(" 0.00 ") ! Pu-242 fraction weapon grade Pu !
$Am1= PAR(" 0.0030 ") ! Am-241 fraction weapon grade Pu !
!           $RhoFul = PAR ("10.000") Fuel density UO2 w/o Gd [g/cm3]. !
!           $RhoFum = PAR ("10.000") Fuel density MO2 w/o Gd [g/cm3] !
!           $RhoFG1 = PAR ("9.3000/1.00") Fuel density w/ Gd [g/cm3] !
$RhoFul = PAR ("10.450")! NCSU, 2-23-98 Fuel density UO2 w/o Gd [g/cm3] !
$RhoFum = PAR ("10.450")! Adopted,2-23-98 Fuel density MO2 w/o Gd [g/cm3] !
$RhoFG1 = PAR ("10.331")! NCSU 2-23-98 Fuel density w/ Gd [g/cm3] !
!*****
! END : Common input for all cases Fmdp GE-11 !
! *****
$denr      = PAR ("-0.15")

'UO2-1' = MAT (" $RhoFul" / 92235,"2.2+$denr"; 92238,"97.8-$denr"; 8001, 0)
'UO2-2' = MAT (" $RhoFul" / 92235,"3.0+$denr"; 92238,"97.0-$denr"; 8001, 0)
'UO2-3' = MAT (" $RhoFul" / 92235,"3.6+$denr"; 92238,"96.4-$denr"; 8001, 0)
'UO2-4' = MAT (" $RhoFul" / 92235,"4.2+$denr"; 92238,"95.8-$denr"; 8001, 0)
'UO2-G1' = MAT (" $RhoFG1" / 92235,"3.60+$denr"; 92238,"96.40-$denr"; 8001, 0;
              64000,6.5)
'UO2-H1' = MAT (" $RhoFG1" / 92235,"3.60+$denr"; 92238,"96.40-$denr"; 8001, 0)

'UO2-MO2-1' = MAT (" $RhoFul" / 92235,"2.4+$denr"; 92238,"97.3-$denr"; 8001, 0)
'UO2-MO2-2' = MAT (" $RhoFul" / 92235,"3.4+$denr"; 92238,"96.6-$denr"; 8001, 0)
'UO2-MO2-4' = MAT (" $RhoFul" / 92235,"4.4+$denr"; 92238,"95.6-$denr"; 8001, 0)
'UO2-MO2-3' = MAT (" $RhoFul" / 92235,"4.6+$denr"; 92238,"95.4-$denr"; 8001, 0)

! ----- Other materials ----- !
Zircaloy2 = MAT ( / 40002,"$sml* 4.2918E-2") ! sml: smear clad in gap!
SS304      = MAT (8.027/ 26001, 100)
B4C        = MAT (1.764/ 5000, 78.26; 6000,21.74)
U5det      = MAT (NB // 92235,1E-7)

! ===== GEOMETRY ===== !

```

```

Upin1      = CCS($Upin1)
Gpin1      = CCS($Gpin1)
Wpin1      = CCS($Wpin1)

'3.00'      = STR ($'Ucell-1')      .! UO2 cell w/ pin radius $rco1 !
'3.60'      = STR ($'Ucell-1')      ! UO2 cell w/ pin radius $rco1 !
'4.20'      = STR ($'Ucell-1')      ! UO2 cell w/ pin radius $rco1 !
'2.3p'      = STR ($'Ucell-1')      ! MO2 cell w/ pin radius $rco1 !
'3.6p'      = STR ($'Ucell-1')      ! MO2 cell w/ pin radius $rco1 !
'5.4p'      = STR ($'Ucell-1')      ! MO2 cell w/ pin radius $rco1 !
'5.0p'      = STR ($'Ucell-1')      ! MO2 cell w/ pin radius $rco1 !
'2.2c'      = STR ($'Ucell-c1')      ! UO2 Corner cell, pin radius $rco1 !
'4.5g'      = STR ($'Gcell-1')      ! Gad cell w/ pin radius $rco1 !
'4.5h'      = STR ($'Ucell-1')      ! Gad cell w/ pin radius $rco1 !
WR          = STR ($'Wcell-1')      ! Water cells rods radius $rwo1 !

$Fuel       = PAR (
    'UO2-2' /*-'3.00'--(fuel1,fuel2)/
    'UO2-3' /*-'3.60'--(fuel1,fuel2)/
    'UO2-4' /*-'4.20'--(fuel1,fuel2)/
    'UO2-MO2-1' /*-'2.3p'--(fuel1,fuel2)/
    'UO2-MO2-2' /*-'3.6p'--(fuel1,fuel2)/
    'UO2-MO2-3' /*-'5.4p'--(fuel1,fuel2)/
    'UO2-MO2-4' /*-'5.0p'--(fuel1,fuel2)/
    'UO2-1' /*-'2.2c'--(fuel1,fuel2)/
    'UO2-G1' /*-'4.5g'--(fuel1,fuel2)/
    'UO2-H1' /*-'4.5h'--(fuel1,fuel2)/
!*****!
!
! Lower section of cluster: 26 Pu rods, 16 4.5%Gd Rods !
!
!*****!
!          1          2          3          4          5          6          7          8          9          !
$FuelPins=PAR(
    '2.2c','3.00','3.60','4.20','4.20','4.20','3.60','3.00','2.2c',!1!
    '3.00','2.3p','3.6p','4.5g','5.0p','4.5g','3.6p','2.3p','3.00',!2!
    '3.60','3.6p','5.4p','5.4p','4.5h','5.4p','4.5g','3.6p','3.60',!3!
    '4.20','4.5g','5.4p','4.5h'          , '5.4p','4.5g','4.20',!4!
    '4.20','5.0p','4.5h'          , WR          , '4.5h','5.0p','4.20',!5!
    '4.20','4.5g','5.4p'          , '4.5h','5.4p','4.5g','4.20',!6!
    '3.60','3.6p','4.5g','5.4p','4.5h','5.4p','5.4p','3.6p','3.60',!7!
    '3.00','2.3p','3.6p','4.5g','5.0p','4.5g','3.6p','2.3p','3.00',!8!
    '2.2c','3.00','3.60','4.20','4.20','4.20','3.60','3.00','2.2c')!9!
!
! Number MOX rods : 5 + 5 + 2 + 2 + 2 + 5 + 5 = 26 !
! per column
!
! ----- STATES DEFINITION ----- used in: ----- !
u1      = STAT(mu1, dos, tosh, $pow)      ! Uncontrolled 0 % void(Low ) !
u2      = STAT(mu2, dos, tosh, $pow)      ! " " 40 % void(Inter) !
u3      = STAT(mu3, dos, tosh, $pow)      ! " " 70 % void(High) !
c1      = STAT(mcl, dos, tosh, $pow)      ! Controlled 0 % void(Low ) !
dpl     = STAT(mu1, dos, tosd, $pow)      ! fuel temperature decrease !
uc      = STAT(mcu, dos, tosc, noXe,0.0001) ! uncontrolled cold zero power !
cc      = STAT(mcc, dos, tosc, noXe,0.0001) ! controlled cold zero power !
! ----- < Depletion > ----- !

```

```

BASE      = PATH (    /(u1) , $casebase)
BRANCH1   = TREE(BASE/(u2) /$casebranch)    ! Void 1          !
BRANCH2   = TREE(BASE/(u3) /$casebranch)    ! Void 2          !
BRANCH3   = TREE(BASE/(dp1)/$casebranch)    ! Tfuel Decrease !
BRANCH4   = TREE(BASE/(c1) /$casebranch)    ! HFP Rodded     !
BRANCH5   = TREE(BASE/(uc) /$casebranch)    ! CZP unrodded  !
BRANCH6   = TREE(BASE/(cc) /$casebranch)    ! CZP rodded     !

$casebase = PAR(500,13500/26,15000,17000,20000,40000/8,60000/4)
$casebranch = PAR(0,1000,2000,2500,3000,12000/9,13000/2,15000,17000,20000,
50000/6,60000)
Lc611     = RUN ( )

```

A2. ZENITH Sample Input/Output File

The following is a ZENITH input/output (input file is contained in the output file) file for the lower axial segment of the LEU enrichment 2 lattice.

```

1<<< Z E N I T H >>>      Version: 1.4      <<< Z E N I T H >>>
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0001 BEGIN ('BWR XS GE 11 FCD')
0002
0003 $Hcase   = PAR('Lc611')
0004 $Hfile   = PAR('lleulower0.hrf')
0005 C1       = IMP(HELIOS; $Hcase/$Hfile)
0006
0007 $Bubase   = PAR(0,500,1000,1500,2000,2500,3000,3500,4000,4500,5000,5500,6000,6500,
0008             7000,7500,8000,8500,9000,9500,10000,10500,11000,11500,12000,12500,
0009             13000,13500,15000,17000,20000,22500,25000,27500,30000,32500,35000,
0010             37500,40000,45000,50000,55000,60000)
0011 $Bubran   = PAR(0,1000,2000,2500,3000,4000,5000,6000,7000,8000,9000,10000,11000,
0012             12000,12500,13000,15000,17000,20000,25000,30000,35000,40000,45000,
0013             50000,60000)
0014
0015 $Path1     = PAR('BASE')
0016 $Path2     = PAR('BRANCH1')
0017 $Path3     = PAR('BRANCH2')
0018 $Path4     = PAR('BRANCH3')
0019 $Path5     = PAR('BRANCH4')
0020 $Path6     = PAR('BRANCH5')
0021 $Path7     = PAR('BRANCH6')
0022 $State1    = PAR('u1')
0023 $State2    = PAR('u2')
0024 $State3    = PAR('u3')
0025 $State4    = PAR('dp1')
0026 $State5    = PAR('c1')
0027 $State6    = PAR('uc')
0028 $State7    = PAR('cc')
0029

```

```

0030 npins      = FOR(74)
0031 voiref     = FOR(0.0)
0032 tfuref     = FOR(792.5)
0033 tmoref     = FOR(560.0)
0034 tmocold    = FOR(293.0)
0035 voichg1    = FOR(40.0)
0036 voichg2    = FOR(70.0)
0037 voicold    = FOR(0.0)
0038 ibap       = FOR(10)
0039 ibao       = FOR(ibap)
0040 wba        = FOR(6.5)
0041 enr        = FOR(3.520)
0042
0043 CASE       = LIS('/General Param'/E/f0:npins;ibap;ibao;f2:wba;enr)
0044
0045 !---CASE 1 : BASE CASE---!
0046 $scalp     = PAR($Path1:($State1)$Bubase)
0047 voichg     = FOR(voiref)
0048 tfuchg     = FOR(tfuref)
0049 tmochg     = FOR(tmoref)
0050 CASE       = LIS('/Case1: Base'/E/f2: voichg;voiref;tfuchg;tfuref;tmochg;tmoref)
0051
0052 $macALL2    = PAR(NArea2)
0053 $micALL2    = PAR(nArea2)
0054 $macALL     = PAR(NArea1)
0055 $micALL     = PAR(nArea1)
0056 $macPin    = PAR(NFmap1)
0057
1<<< Z E N I T H >>>      Version: 1.4      <<< Z E N I T H >>>
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0058 bu        = SEL(uburn/MAC/C1;$macALL2/$scalp)
0059 BURNUP     = LIS('/Bundle Burnup'/E/f0:bu)
0060
0061 !---Surface ADFs---!
0062 jp         = SEL(jp/CUR/ C1;Currents/$scalp)
0063 jm         = SEL(jm/CUR/ C1;Currents/$scalp)
0064 fx         = SEL(fx/MAC/ C1;$macALL2/$scalp)
0065 inorth     = IND(jp/RAN:2;;;)
0066 ieast     = IND(jp/RAN:5;;;)
0067 isouth     = IND(jp/RAN:7;;;)
0068 iwest     = IND(jp/RAN:4;;;)
0069 Sides     = FOR(2*(jp+jm)/fx)
0070 adfN      = FOR(Sides^inorth)
0071 adfE      = FOR(Sides^ieast)
0072 adfS      = FOR(Sides^isouth)
0073 adfW      = FOR(Sides^iwest)
0074 ADF       = LIS(;;9/'ADFs'/E/f0:bu;e5:adfN;adfE;adfS;adfW)
0075
0076 !---Fission Product Yields---!
0077 nd        = SEL(nd/MIC/C1;$micALL/$scalp)
0078 nI        = SEL(nd/MIC/C1;$micALL/$scalp/53635)
0079 nXe       = SEL(nd/MIC/C1;$micALL/$scalp/54635)
0080 nPm       = SEL(nd/MIC/C1;$micALL/$scalp/61649)
0081 aI       = SEL(ab/MIC/C1;$micALL/$scalp/53635)
0082 aXe       = SEL(ab/MIC/C1;$micALL/$scalp/54635)
0083 aPm       = SEL(ab/MIC/C1;$micALL/$scalp/61649)
0084 fx       = SEL(fx/MIC/C1;$micALL/$scalp)
0085 fi       = SEL(fi/MIC/C1;$micALL/$scalp)
0086 vo       = SEL(vo/MIC/C1;$micALL/$scalp)
0087 fimac    = FOR(@smI(nd*fi))

```

```

0088 avfxfi = FOR(@smR(fx*fimac*vo)/@smR(vo))
0089 avfxaI = FOR(@smR(fx*aI*vo) /@smR(vo))
0090 avfxaXe = FOR(@smR(fx*aXe*vo) /@smR(vo))
0091 avfxaPm = FOR(@smR(fx*aPm*vo) /@smR(vo))
0092 'N(I)' = FOR(@smR(nI*vo) /@smR(vo))
0093 'N(Xe)' = FOR(@smR(nXe*vo)/@smR(vo))
0094 'N(Pm)' = FOR(@smR(nPm*vo)/@smR(vo))
0095 $lambdaI = PAR(2.875E-5) !--- lambda : unit=cm-1 ---!
0096 $lambdaXe = PAR(2.092E-5)
0097 $lambdaPm = PAR(3.556E-6)
0098 'Yield(I)' = FOR(1E24*'N(I)')*$lambdaI/avfxfi)
0099 'Yield(Xe)' = FOR(1E24*'N(Xe)')*(avfxaXe*1E-24+$lambdaXe)/avfxfi-'Yield(I)')
0100 'Yield(Pm)' = FOR(1E24*'N(Pm)')*$lambdaPm/avfxfi)
0101 FPYIELDS = LIS('/'FPYIELDS'/E/f0:bu; e5:'Yield(I)';'Yield(Xe)';'Yield(Pm)')
0102
0103 !---Xenon Samarium---!
0104 micxe = SEL(ab/MIC/C1;$micALL2/$scalp/54635)
0105 ndxe = SEL(nd/MIC/C1;$micALL2/$scalp/54635)
0106 macxe = FOR(micxe*ndxe)
0107 micsm = SEL(ab/MIC/C1;$micALL2/$scalp/62649)
0108 ndsm = SEL(nd/MIC/C1;$micALL2/$scalp/62649)
0109 macsm = FOR(micsm*ndsm)
0110 XESM = LIS('/'XESM'/E/f0:bu; e5: micxe;macxe;micsm;macsm)
0111
0112 !---kinf,prel,ppblr---!
0113 kinf = SEL(kinf /MAC/C1;$macALL2/$scalp)
0114 fx = SEL(fx/MAC/C1;$macPin/$scalp)
1<<< Z E N I T H >>> Version: 1.4 <<< Z E N I T H >>>
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0115 kf = SEL(kf/MAC/C1;$macPin/$scalp)
0116 vo = SEL(vo/MAC/C1;$macPin/$scalp)
0117 vx = SEL(vx/MAC/C1;$macPin/$scalp)
0118 vy = SEL(vy/MAC/C1;$macPin/$scalp)
0119 bupin = SEL(bu/MAC/C1;$macPin/$scalp)
0120 Power = FOR(fx*kf*vo)
0121 AvePower = FOR((@smR(Power*vo))/@smR(vo))
0122 PP = FOR(Power/AvePower)
0123 prel = FOR(@mxR(PP))
0124 ppblr = FOR(@mxR(bupin))
0125 PINTOBOX = LIS('/'PINTOBOX'/E/f0:bu; f5:kinf;prel;ppblr)
0126
0127 !---Macro XS---!
0128 dr = SEL(dr/MAC/C1;$macALL2/$scalp)
0129 tr = SEL(tr/MAC/C1;$macALL2/$scalp)
0130 ab = SEL(ab/MAC/C1;$macALL2/$scalp)
0131 nf = SEL(nf/MAC/C1;$macALL2/$scalp)
0132 kf = SEL(kf/MAC/C1;$macALL2/$scalp)
0133 p0 = SEL(p0/MAC/C1;$macALL2/$scalp)
0134 fx = SEL(fx/MAC/C1;$macALL2/$scalp)
0135 i12 = IND(p0/RAN:;;2;1)
0136 i21 = IND(p0/RAN:;;1;2)
0137 i1 = IND(nf/RAN:;;1;)
0138 i2 = IND(nf/RAN:;;2;)
0139 diff = FOR(dr/(3.0*tr))
0140 d1 = FOR(diff^i1)
0141 d2 = FOR(diff^i2)
0142 s12 = FOR(p0^i12)
0143 s21 = FOR(p0^i21)
0144 fx1 = FOR(fx^i1)
0145 fx2 = FOR(fx^i2)

```

```

0146 s12net      = FOR(s12-s21*fx2/fx1)
0147 ab1          = FOR(ab^i1)
0148 ab2          = FOR(ab^i2)
0149 nsigf1       = FOR(nf^i1)
0150 nsigf2       = FOR(nf^i2)
0151 ksigf1       = FOR(kf^i1)
0152 ksigf2       = FOR(kf^i2)
0153 nf           = SEL(nf/MAC/C1;$macALL/$scalp)
0154 kf           = SEL(kf/MAC/C1;$macALL/$scalp)
0155 fi           = SEL(fi/MAC/C1;$macALL/$scalp)
0156 nu           = FOR(nf/fi)
0157 kappa        = FOR(kf/fi)
0158 'MACRO-FAST'   = LIS(/'MACRO-FAST'/E/f0:bu; e5: d1;s12net;ab1;nsigf1;ksigf1)
0159 'MACRO-THERMAL' = LIS(/'MACRO-THERMAL'/E/f0:bu; e5: d2;ab2;nsigf2;ksigf2;nu;kappa)
0160
0161
0162 !---CASE 2 : BRANCH 1 VOID DECREASE---!
0163 $scalp        = PAR($Path2:($State2)$Bubran)
0164 voichg         = FOR(voichg1)
0165 tfuchg         = FOR(tfuref)
0166 tmochg         = FOR(tmoref)
0167 CASE          = LIS(/'Case2: Void Decrease'/E/f2:
voichg;voiref;tfuchg;tfuref;tmochg;tmoref)
0168
0169 bu             = SEL(uburn/MAC/C1;$macALL2/$scalp)
0170 BURNUP         = LIS(/'Bundle Burnup'/E/f0:bu)
0171
1<<< Z E N I T H >>>      Version: 1.4
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<<< Z E N I T H >>>

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0172 !---Surface ADFs---!
0173 jp           = SEL(jp/CUR/ C1;Currents/$scalp)
0174 jm           = SEL(jm/CUR/ C1;Currents/$scalp)
0175 fx           = SEL(fx/MAC/ C1;$macALL2/$scalp)
0176 inorth       = IND(jp/RAN:2;;;)
0177 ieast        = IND(jp/RAN:5;;;)
0178 isouth       = IND(jp/RAN:7;;;)
0179 iwest        = IND(jp/RAN:4;;;)
0180 Sides        = FOR(2*(jp+jm)/fx)
0181 adfN         = FOR(Sides^inorth)
0182 adfE         = FOR(Sides^ieast)
0183 adfS         = FOR(Sides^isouth)
0184 adfW         = FOR(Sides^iwest)
0185 ADF          = LIS(;;9/'ADFs'/E/f0:bu;e5:adfN;adfE;adfS;adfW)
0186
0187 !---Fission Product Yields---!
0188 nd           = SEL(nd/MIC/C1;$micALL/$scalp)
0189 nI           = SEL(nd/MIC/C1;$micALL/$scalp/53635)
0190 nXe          = SEL(nd/MIC/C1;$micALL/$scalp/54635)
0191 nPm          = SEL(nd/MIC/C1;$micALL/$scalp/61649)
0192 aI           = SEL(ab/MIC/C1;$micALL/$scalp/53635)
0193 aXe          = SEL(ab/MIC/C1;$micALL/$scalp/54635)
0194 aPm          = SEL(ab/MIC/C1;$micALL/$scalp/61649)
0195 fx          = SEL(fx/MIC/C1;$micALL/$scalp)
0196 fi          = SEL(fi/MIC/C1;$micALL/$scalp)
0197 vo          = SEL(vo/MIC/C1;$micALL/$scalp)
0198 fimac        = FOR(@smI(nd*fi))
0199 avfxfi       = FOR(@smR(fx*fimac*vo)/@smR(vo))
0200 avfxaI       = FOR(@smR(fx*aI*vo) /@smR(vo))
0201 avfxaXe      = FOR(@smR(fx*aXe*vo) /@smR(vo))
0202 avfxaPm      = FOR(@smR(fx*aPm*vo) /@smR(vo))

```



```

0203 'N(I)' = FOR(@smR(nI*vo) /@smR(vo))
0204 'N(Xe)' = FOR(@smR(nXe*vo) /@smR(vo))
0205 'N(Pm)' = FOR(@smR(nPm*vo) /@smR(vo))
0206 $lambdaI = PAR(2.875E-5) !--- lambda : unit=cm-1 ---!
0207 $lambdaXe = PAR(2.092E-5)
0208 $lambdaPm = PAR(3.556E-6)
0209 'Yield(I)' = FOR(1E24*'N(I) '*$lambdaI/avfxfi)
0210 'Yield(Xe)' = FOR(1E24*'N(Xe) '* (avfxaXe*1E-24+$lambdaXe)/avfxfi-'Yield(I)')
0211 'Yield(Pm)' = FOR(1E24*'N(Pm) '*$lambdaPm/avfxfi)
0212 FPYIELDS = LIS('/'FPYIELDS'/E/f0:bu; e5:'Yield(I)';'Yield(Xe)';'Yield(Pm)')
0213
0214 !---Xenon Samarium---!
0215 micxe = SEL(ab/MIC/C1;$micALL2/$scalp/54635)
0216 ndxe = SEL(nd/MIC/C1;$micALL2/$scalp/54635)
0217 macxe = FOR(micxe*ndxe)
0218 micsm = SEL(ab/MIC/C1;$micALL2/$scalp/62649)
0219 ndsm = SEL(nd/MIC/C1;$micALL2/$scalp/62649)
0220 macsm = FOR(micsm*ndsm)
0221 XESM = LIS('/'XESM'/E/f0:bu; e5: micxe;macxe;micsm;macsm)
0222
0223 !---kinf,prel,ppblr---!
0224 kinf = SEL(kinf /MAC/C1;$macALL2/$scalp)
0225 fx = SEL(fx/MAC/C1;$macPin/$scalp)
0226 kf = SEL(kf/MAC/C1;$macPin/$scalp)
0227 vo = SEL(vo/MAC/C1;$macPin/$scalp)
0228 vx = SEL(vx/MAC/C1;$macPin/$scalp)
1<<< Z E N I T H >>> Version: 1.4 <<< Z E N I T H >>>
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```

```

0229 vy = SEL(vy/MAC/C1;$macPin/$scalp)
0230 bupin = SEL(bu/MAC/C1;$macPin/$scalp)
0231 Power = FOR(fx*kf*vo)
0232 AvePower = FOR((@smR(Power*vo))/@smR(vo))
0233 PP = FOR(Power/AvePower)
0234 prel = FOR(@mxR(PP))
0235 ppblr = FOR(@mxR(bupin))
0236 PINTOBOX = LIS('/'PINTOBOX'/E/f0:bu; f5:kinf;prel;ppblr)
0237
0238 !---Macro XS---!
0239 dr = SEL(dr/MAC/C1;$macALL2/$scalp)
0240 tr = SEL(tr/MAC/C1;$macALL2/$scalp)
0241 ab = SEL(ab/MAC/C1;$macALL2/$scalp)
0242 nf = SEL(nf/MAC/C1;$macALL2/$scalp)
0243 kf = SEL(kf/MAC/C1;$macALL2/$scalp)
0244 p0 = SEL(p0/MAC/C1;$macALL2/$scalp)
0245 fx = SEL(fx/MAC/C1;$macALL2/$scalp)
0246 i12 = IND(p0/RAN;;;2;1)
0247 i21 = IND(p0/RAN;;;1;2)
0248 i1 = IND(nf/RAN;;;1;)
0249 i2 = IND(nf/RAN;;;2;)
0250 diff = FOR(dr/(3.0*tr))
0251 d1 = FOR(diff^i1)
0252 d2 = FOR(diff^i2)
0253 s12 = FOR(p0^i12)
0254 s21 = FOR(p0^i21)
0255 fx1 = FOR(fx^i1)
0256 fx2 = FOR(fx^i2)
0257 s12net = FOR(s12-s21*fx2/fx1)
0258 ab1 = FOR(ab^i1)
0259 ab2 = FOR(ab^i2)
0260 nsigf1 = FOR(nf^i1)

```

```

0261 nsigf2      = FOR(nf^i2)
0262 ksigf1      = FOR(kf^i1)
0263 ksigf2      = FOR(kf^i2)
0264 nf          = SEL(nf/MAC/C1;$macALL/$scalp)
0265 kf          = SEL(kf/MAC/C1;$macALL/$scalp)
0266 fi          = SEL(fi/MAC/C1;$macALL/$scalp)
0267 nu          = FOR(nf/fi)
0268 kappa       = FOR(kf/fi)
0269 'MACRO-FAST'  = LIS(/'MACRO-FAST'/E/f0:bu; e5: d1;s12net;ab1;nsigf1;ksigf1)
0270 'MACRO-THERMAL' = LIS(/'MACRO-THERMAL'/E/f0:bu; e5: d2;ab2;nsigf2;ksigf2;nu;kappa)
0271
0272
0273 !---CASE 3 : BRANCH 2 VOID INCREASE---!
0274 $scalp       = PAR($Path3:($State3)$Bubran)
0275 voichg       = FOR(voichg2)
0276 tfuchg       = FOR(tfuref)
0277 tmochg       = FOR(tmoref)
0278 CASE         = LIS(/'Case3: Void Increase'/E/f2:
voichg;voiref;tfuchg;tfuref;tmochg;tmoref)
0279
0280 bu           = SEL(uburn/MAC/C1;$macALL2/$scalp)
0281 BURNUP       = LIS(/'Bundle Burnup'/E/f0:bu)
0282
0283 !---Surface ADFs---!
0284 jp           = SEL(jp/CUR/ C1;Currents/$scalp)
0285 jm           = SEL(jm/CUR/ C1;Currents/$scalp)
1<<< Z E N I T H >>>      Version: 1.4      <<< Z E N I T H >>>
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0286 fx         = SEL(fx/MAC/ C1;$macALL2/$scalp)
0287 inorth      = IND(jp/RAN:2;;;)
0288 ieast       = IND(jp/RAN:5;;;)
0289 isouth      = IND(jp/RAN:7;;;)
0290 iwest       = IND(jp/RAN:4;;;)
0291 Sides       = FOR(2*(jp+jm)/fx)
0292 adfN        = FOR(Sides^inorth)
0293 adfE        = FOR(Sides^ieast)
0294 adfS        = FOR(Sides^isouth)
0295 adfW        = FOR(Sides^iwest)
0296 ADF         = LIS(;;9/'ADFs'/E/f0:bu;e5:adfN;adfE;adfS;adfW)
0297
0298 !---Fission Product Yields---!
0299 nd          = SEL(nd/MIC/C1;$micALL/$scalp)
0300 nI          = SEL(nd/MIC/C1;$micALL/$scalp/53635)
0301 nXe        = SEL(nd/MIC/C1;$micALL/$scalp/54635)
0302 nPm        = SEL(nd/MIC/C1;$micALL/$scalp/61649)
0303 aI         = SEL(ab/MIC/C1;$micALL/$scalp/53635)
0304 aXe        = SEL(ab/MIC/C1;$micALL/$scalp/54635)
0305 aPm        = SEL(ab/MIC/C1;$micALL/$scalp/61649)
0306 fx         = SEL(fx/MIC/C1;$micALL/$scalp)
0307 fi         = SEL(fi/MIC/C1;$micALL/$scalp)
0308 vo         = SEL(vo/MIC/C1;$micALL/$scalp)
0309 fimac       = FOR(@smI(nd*fi))
0310 avfxfi      = FOR(@smR(fx*fimac*vo)/@smR(vo))
0311 avfxaI      = FOR(@smR(fx*aI*vo) /@smR(vo))
0312 avfxaXe     = FOR(@smR(fx*aXe*vo) /@smR(vo))
0313 avfxaPm     = FOR(@smR(fx*aPm*vo) /@smR(vo))
0314 'N(I)'      = FOR(@smR(nI*vo) /@smR(vo))
0315 'N(Xe)'     = FOR(@smR(nXe*vo) /@smR(vo))
0316 'N(Pm)'     = FOR(@smR(nPm*vo) /@smR(vo))
0317 $lambdaI    = PAR(2.875E-5)      !--- lambda : unit=cm-1 ---!

```

```

0318 $lambdaXe = PAR(2.092E-5)
0319 $lambdaPm = PAR(3.556E-6)
0320 'Yield(I)' = FOR(1E24*'N(I)')*$lambdaI/avfxfi)
0321 'Yield(Xe)' = FOR(1E24*'N(Xe)')*(avfxaXe*1E-24+$lambdaXe)/avfxfi-'Yield(I)')
0322 'Yield(Pm)' = FOR(1E24*'N(Pm)')*$lambdaPm/avfxfi)
0323 FPYIELDS = LIS('/'FPYIELDS'/E/f0:bu; e5:'Yield(I)';'Yield(Xe)';'Yield(Pm)')
0324
0325 !---Xenon Samarium---!
0326 micxe = SEL(ab/MIC/C1;$micALL2/$scalp/54635)
0327 ndxe = SEL(nd/MIC/C1;$micALL2/$scalp/54635)
0328 macxe = FOR(micxe*ndxe)
0329 micsm = SEL(ab/MIC/C1;$micALL2/$scalp/62649)
0330 ndsm = SEL(nd/MIC/C1;$micALL2/$scalp/62649)
0331 macsm = FOR(micsm*ndsm)
0332 XESM = LIS('/'XESM'/E/f0:bu; e5: micxe;macxe;micsm;macsm)
0333
0334 !---kinf,prel,ppblr---!
0335 kinf = SEL(kinf /MAC/C1;$macALL2/$scalp)
0336 fx = SEL(fx/MAC/C1;$macPin/$scalp)
0337 kf = SEL(kf/MAC/C1;$macPin/$scalp)
0338 vo = SEL(vo/MAC/C1;$macPin/$scalp)
0339 vx = SEL(vx/MAC/C1;$macPin/$scalp)
0340 vy = SEL(vy/MAC/C1;$macPin/$scalp)
0341 bupin = SEL(bu/MAC/C1;$macPin/$scalp)
0342 Power = FOR(fx*kf*vo)
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0343 AvePower = FOR(@smR(Power*vo))/@smR(vo))
0344 PP = FOR(Power/AvePower)
0345 prel = FOR(@mxR(PP))
0346 ppblr = FOR(@mxR(bupin))
0347 PINTOBOX = LIS('/'PINTOBOX'/E/f0:bu; f5:kinf;prel;ppblr)
0348
0349 !---Macro XS---!
0350 dr = SEL(dr/MAC/C1;$macALL2/$scalp)
0351 tr = SEL(tr/MAC/C1;$macALL2/$scalp)
0352 ab = SEL(ab/MAC/C1;$macALL2/$scalp)
0353 nf = SEL(nf/MAC/C1;$macALL2/$scalp)
0354 kf = SEL(kf/MAC/C1;$macALL2/$scalp)
0355 p0 = SEL(p0/MAC/C1;$macALL2/$scalp)
0356 fx = SEL(fx/MAC/C1;$macALL2/$scalp)
0357 i12 = IND(p0/RAN;;;2;1)
0358 i21 = IND(p0/RAN;;;1;2)
0359 i1 = IND(nf/RAN;;;1;)
0360 i2 = IND(nf/RAN;;;2;)
0361 diff = FOR(dr/(3.0*tr))
0362 d1 = FOR(diff^i1)
0363 d2 = FOR(diff^i2)
0364 s12 = FOR(p0^i12)
0365 s21 = FOR(p0^i21)
0366 fx1 = FOR(fx^i1)
0367 fx2 = FOR(fx^i2)
0368 s12net = FOR(s12-s21*fx2/fx1)
0369 ab1 = FOR(ab^i1)
0370 ab2 = FOR(ab^i2)
0371 nsigf1 = FOR(nf^i1)
0372 nsigf2 = FOR(nf^i2)
0373 ksigf1 = FOR(kf^i1)
0374 ksigf2 = FOR(kf^i2)
0375 nf = SEL(nf/MAC/C1;$macALL/$scalp)

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0376 kf      = SEL(kf/MAC/C1;$macALL/$scalp)
0377 fi      = SEL(fi/MAC/C1;$macALL/$scalp)
0378 nu      = FOR(nf/fi)
0379 kappa   = FOR(kf/fi)
0380 'MACRO-FAST' = LIS('/MACRO-FAST'/E/f0:bu; e5: d1;s12net;ab1;nsigf1;ksigf1)
0381 'MACRO-THERMAL' = LIS('/MACRO-THERMAL'/E/f0:bu; e5: d2;ab2;nsigf2;ksigf2;nu;kappa)
0382
0383
0384 !---CASE 4 : BRANCH 3 TFUEL DECREASE---!
0385 $scalp    = PAR($Path4:($State4)$Bubran)
0386 voichg    = FOR(voiref)
0387 tfuchg    = FOR(tmoref)
0388 tmochg    = FOR(tmoref)
0389 CASE     = LIS('/Case4: Tfuel Decrease'/E/f2:
voichg;voiref;tfuchg;tfuref;tmochg;tmoref)
0390
0391 bu        = SEL(uburn/MAC/C1;$macALL2/$scalp)
0392 BURNUP    = LIS('/Bundle Burnup'/E/f0:bu)
0393
0394 !---Surface ADFs---!
0395 jp        = SEL(jp/CUR/ C1;Currents/$scalp)
0396 jm        = SEL(jm/CUR/ C1;Currents/$scalp)
0397 fx        = SEL(fx/MAC/ C1;$macALL2/$scalp)
0398 inorth    = IND(jp/RAN:2;;;)
0399 ieast     = IND(jp/RAN:5;;;)
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0400 isouth   = IND(jp/RAN:7;;;)
0401 iwest    = IND(jp/RAN:4;;;)
0402 Sides     = FOR(2*(jp+jm)/fx)
0403 adfN      = FOR(Sides^inorth)
0404 adfE      = FOR(Sides^ieast)
0405 adfS      = FOR(Sides^isouth)
0406 adfW      = FOR(Sides^iwest)
0407 ADF       = LIS(;;9/'ADFs'/E/f0:bu;e5:adfN;adfE;adfS;adfW)
0408
0409 !---Fission Product Yields---!
0410 nd        = SEL(nd/MIC/C1;$micALL/$scalp)
0411 nI        = SEL(nd/MIC/C1;$micALL/$scalp/53635)
0412 nXe      = SEL(nd/MIC/C1;$micALL/$scalp/54635)
0413 nPm      = SEL(nd/MIC/C1;$micALL/$scalp/61649)
0414 aI       = SEL(ab/MIC/C1;$micALL/$scalp/53635)
0415 aXe      = SEL(ab/MIC/C1;$micALL/$scalp/54635)
0416 aPm      = SEL(ab/MIC/C1;$micALL/$scalp/61649)
0417 fx       = SEL(fx/MIC/C1;$micALL/$scalp)
0418 fi       = SEL(fi/MIC/C1;$micALL/$scalp)
0419 vo       = SEL(vo/MIC/C1;$micALL/$scalp)
0420 fimac     = FOR(@smI(nd*fi))
0421 avfxfi    = FOR(@smR(fx*fimac*vo)/@smR(vo))
0422 avfxaI    = FOR(@smR(fx*aI*vo) /@smR(vo))
0423 avfxaXe   = FOR(@smR(fx*aXe*vo) /@smR(vo))
0424 avfxaPm   = FOR(@smR(fx*aPm*vo) /@smR(vo))
0425 'N(I)'    = FOR(@smR(nI*vo) /@smR(vo))
0426 'N(Xe)'  = FOR(@smR(nXe*vo) /@smR(vo))
0427 'N(Pm)'  = FOR(@smR(nPm*vo) /@smR(vo))
0428 $lambdaI  = PAR(2.875E-5)      !--- lambda : unit=cm-1 ---!
0429 $lambdaXe = PAR(2.092E-5)
0430 $lambdaPm  = PAR(3.556E-6)
0431 'Yield(I)' = FOR(1E24*'N(I)')*$lambdaI/avfxfi)
0432 'Yield(Xe)' = FOR(1E24*'N(Xe)')*(avfxaXe*1E-24+$lambdaXe)/avfxfi-'Yield(I)')

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0433 'Yield(Pm)' = FOR(1E24*'N(Pm)')*$lambdaPm/avfxfi)
0434 FPYIELDS = LIS(/'FPYIELDS'/E/f0:bu; e5:'Yield(I)';'Yield(Xe)';'Yield(Pm)')
0435
0436 !---Xenon Samarium---!
0437 micxe = SEL(ab/MIC/C1;$micALL2/$scalp/54635)
0438 ndxe = SEL(nd/MIC/C1;$micALL2/$scalp/54635)
0439 macxe = FOR(micxe*ndxe)
0440 micsm = SEL(ab/MIC/C1;$micALL2/$scalp/62649)
0441 ndsm = SEL(nd/MIC/C1;$micALL2/$scalp/62649)
0442 macsm = FOR(micsm*ndsm)
0443 XESM = LIS(/'XESM'/E/f0:bu; e5: micxe;macxe;micsm;macsm)
0444
0445 !---kinf,prel,ppblr---!
0446 kinf = SEL(kinf /MAC/C1;$macALL2/$scalp)
0447 fx = SEL(fx/MAC/C1;$macPin/$scalp)
0448 kf = SEL(kf/MAC/C1;$macPin/$scalp)
0449 vo = SEL(vo/MAC/C1;$macPin/$scalp)
0450 vx = SEL(vx/MAC/C1;$macPin/$scalp)
0451 vy = SEL(vy/MAC/C1;$macPin/$scalp)
0452 bupin = SEL(bu/MAC/C1;$macPin/$scalp)
0453 Power = FOR(fx*kf*vo)
0454 AvePower = FOR((@smR(Power*vo))/@smR(vo))
0455 PP = FOR(Power/AvePower)
0456 prel = FOR(@mxR(PP))
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0457 ppblr = FOR(@mxR(bupin))
0458 PINTOBOX = LIS(/'PINTOBOX'/E/f0:bu; f5:kinf;prel;ppblr)
0459
0460 !---Macro XS---!
0461 dr = SEL(dr/MAC/C1;$macALL2/$scalp)
0462 tr = SEL(tr/MAC/C1;$macALL2/$scalp)
0463 ab = SEL(ab/MAC/C1;$macALL2/$scalp)
0464 nf = SEL(nf/MAC/C1;$macALL2/$scalp)
0465 kf = SEL(kf/MAC/C1;$macALL2/$scalp)
0466 p0 = SEL(p0/MAC/C1;$macALL2/$scalp)
0467 fx = SEL(fx/MAC/C1;$macALL2/$scalp)
0468 i12 = IND(p0/RAN;;;2;1)
0469 i21 = IND(p0/RAN;;;1;2)
0470 i1 = IND(nf/RAN;;;1;)
0471 i2 = IND(nf/RAN;;;2;)
0472 diff = FOR(dr/(3.0*tr))
0473 d1 = FOR(diff^i1)
0474 d2 = FOR(diff^i2)
0475 s12 = FOR(p0^i12)
0476 s21 = FOR(p0^i21)
0477 fx1 = FOR(fx^i1)
0478 fx2 = FOR(fx^i2)
0479 s12net = FOR(s12-s21*fx2/fx1)
0480 ab1 = FOR(ab^i1)
0481 ab2 = FOR(ab^i2)
0482 nsigf1 = FOR(nf^i1)
0483 nsigf2 = FOR(nf^i2)
0484 ksigf1 = FOR(kf^i1)
0485 ksigf2 = FOR(kf^i2)
0486 nf = SEL(nf/MAC/C1;$macALL/$scalp)
0487 kf = SEL(kf/MAC/C1;$macALL/$scalp)
0488 fi = SEL(fi/MAC/C1;$macALL/$scalp)
0489 nu = FOR(nf/fi)
0490 kappa = FOR(kf/fi)

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0491 'MACRO-FAST'      = LIS('/MACRO-FAST'/E/f0:bu; e5: d1;s12net;ab1;nsigf1;ksigf1)
0492 'MACRO-THERMAL'   = LIS('/MACRO-THERMAL'/E/f0:bu; e5: d2;ab2;nsigf2;ksigf2;nu;kappa)
0493
0494
0495 !---CASE 5 : BRANCH 4 HFP CONTROLLED---!
0496 $scalp      = PAR($Path5:($State5)$Bubran)
0497 voichg      = FOR(voiref)
0498 tfuchg      = FOR(tfuref)
0499 tmochg      = FOR(tmoref)
0500 CASE        = LIS('/Case5: HFP Controlled'/E/f2:
voichg;voiref;tfuchg;tfuref;tmochg;tmoref)
0501
0502 bu          = SEL(uburn/MAC/C1;$macALL2/$scalp)
0503 BURNUP      = LIS('/Bundle Burnup'/E/f0:bu)
0504
0505 !---Surface ADFs---!
0506 jp          = SEL(jp/CUR/ C1;Currents/$scalp)
0507 jm          = SEL(jm/CUR/ C1;Currents/$scalp)
0508 fx          = SEL(fx/MAC/ C1;$macALL2/$scalp)
0509 inorth      = IND(jp/RAN:2;;;)
0510 ieast       = IND(jp/RAN:5;;;)
0511 isouth      = IND(jp/RAN:7;;;)
0512 iwest      = IND(jp/RAN:4;;;)
0513 Sides       = FOR(2*(jp+jm)/fx)
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0514 adfN      = FOR(Sides^inorth)
0515 adfE      = FOR(Sides^ieast)
0516 adfS      = FOR(Sides^isouth)
0517 adfW      = FOR(Sides^iwest)
0518 ADF       = LIS(;;9/'ADFS'/E/f0:bu;e5:adfN;adfE;adfS;adfW)
0519
0520 !---Fission Product Yields---!
0521 nd          = SEL(nd/MIC/C1;$micALL/$scalp)
0522 nI          = SEL(nd/MIC/C1;$micALL/$scalp/53635)
0523 nXe        = SEL(nd/MIC/C1;$micALL/$scalp/54635)
0524 nPm        = SEL(nd/MIC/C1;$micALL/$scalp/61649)
0525 aI         = SEL(ab/MIC/C1;$micALL/$scalp/53635)
0526 aXe        = SEL(ab/MIC/C1;$micALL/$scalp/54635)
0527 aPm        = SEL(ab/MIC/C1;$micALL/$scalp/61649)
0528 fx         = SEL(fx/MIC/C1;$micALL/$scalp)
0529 fi         = SEL(fi/MIC/C1;$micALL/$scalp)
0530 vo         = SEL(vo/MIC/C1;$micALL/$scalp)
0531 fimac      = FOR(@smI(nd*fi))
0532 avfxfi     = FOR(@smR(fx*fimac*vo)/@smR(vo))
0533 avfxaI     = FOR(@smR(fx*aI*vo) /@smR(vo))
0534 avfxaXe    = FOR(@smR(fx*aXe*vo) /@smR(vo))
0535 avfxaPm    = FOR(@smR(fx*aPm*vo) /@smR(vo))
0536 'N(I)'     = FOR(@smR(nI*vo) /@smR(vo))
0537 'N(Xe)'    = FOR(@smR(nXe*vo) /@smR(vo))
0538 'N(Pm)'    = FOR(@smR(nPm*vo) /@smR(vo))
0539 $lambdaI    = PAR(2.875E-5)      !--- lambda : unit=cm-1 ---!
0540 $lambdaXe   = PAR(2.092E-5)
0541 $lambdaPm   = PAR(3.556E-6)
0542 'Yield(I)'  = FOR(1E24*'N(I)')*$lambdaI/avfxfi)
0543 'Yield(Xe)' = FOR(1E24*'N(Xe)')*(avfxaXe*1E-24+$lambdaXe)/avfxfi-'Yield(I)')
0544 'Yield(Pm)' = FOR(1E24*'N(Pm)')*$lambdaPm/avfxfi)
0545 FPYIELDS    = LIS('/FPYIELDS'/E/f0:bu; e5:'Yield(I)';'Yield(Xe)';'Yield(Pm)')
0546
0547 !---Xenon Samarium---!

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0548 micxe      = SEL(ab/MIC/C1;$micALL2/$scalp/54635)
0549 ndxe       = SEL(nd/MIC/C1;$micALL2/$scalp/54635)
0550 macxe       = FOR(micxe*ndxe)
0551 micsm       = SEL(ab/MIC/C1;$micALL2/$scalp/62649)
0552 ndsm       = SEL(nd/MIC/C1;$micALL2/$scalp/62649)
0553 macsm       = FOR(micsm*ndsm)
0554 XESM        = LIS(/'XESM'/E/f0:bu; e5: micxe;macxe;micsm;macsm)
0555
0556 !---kinf,prel,ppblr---!
0557 kinf        = SEL(kinf /MAC/C1;$macALL2/$scalp)
0558 fx          = SEL(fx/MAC/C1;$macPin/$scalp)
0559 kf          = SEL(kf/MAC/C1;$macPin/$scalp)
0560 vo          = SEL(vo/MAC/C1;$macPin/$scalp)
0561 vx          = SEL(vx/MAC/C1;$macPin/$scalp)
0562 vy          = SEL(vy/MAC/C1;$macPin/$scalp)
0563 bupin       = SEL(bu/MAC/C1;$macPin/$scalp)
0564 Power       = FOR(fx*kf*vo)
0565 AvePower    = FOR((@smR(Power*vo))/@smR(vo))
0566 PP          = FOR(Power/AvePower)
0567 prel       = FOR(@mxR(PP))
0568 ppblr       = FOR(@mxR(bupin))
0569 PINTOBOX    = LIS(/'PINTOBOX'/E/f0:bu; f5:kinf;prel;ppblr)
0570
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0571 !---Macro XS---!
0572 dr          = SEL(dr/MAC/C1;$macALL2/$scalp)
0573 tr          = SEL(tr/MAC/C1;$macALL2/$scalp)
0574 ab          = SEL(ab/MAC/C1;$macALL2/$scalp)
0575 nf          = SEL(nf/MAC/C1;$macALL2/$scalp)
0576 kf          = SEL(kf/MAC/C1;$macALL2/$scalp)
0577 p0          = SEL(p0/MAC/C1;$macALL2/$scalp)
0578 fx          = SEL(fx/MAC/C1;$macALL2/$scalp)
0579 i12         = IND(p0/RAN;;;2;1)
0580 i21         = IND(p0/RAN;;;1;2)
0581 i1          = IND(nf/RAN;;;1;)
0582 i2          = IND(nf/RAN;;;2;)
0583 diff        = FOR(dr/(3.0*tr))
0584 d1          = FOR(diff^i1)
0585 d2          = FOR(diff^i2)
0586 s12         = FOR(p0^i12)
0587 s21         = FOR(p0^i21)
0588 fx1         = FOR(fx^i1)
0589 fx2         = FOR(fx^i2)
0590 s12net      = FOR(s12-s21*fx2/fx1)
0591 ab1         = FOR(ab^i1)
0592 ab2         = FOR(ab^i2)
0593 nsigf1      = FOR(nf^i1)
0594 nsigf2      = FOR(nf^i2)
0595 ksigf1      = FOR(kf^i1)
0596 ksigf2      = FOR(kf^i2)
0597 nf          = SEL(nf/MAC/C1;$macALL/$scalp)
0598 kf          = SEL(kf/MAC/C1;$macALL/$scalp)
0599 fi          = SEL(fi/MAC/C1;$macALL/$scalp)
0600 nu          = FOR(nf/fi)
0601 kappa       = FOR(kf/fi)
0602 'MACRO-FAST' = LIS(/'MACRO-FAST'/E/f0:bu; e5: d1;s12net;ab1;nsigf1;ksigf1)
0603 'MACRO-THERMAL' = LIS(/'MACRO-THERMAL'/E/f0:bu; e5: d2;ab2;nsigf2;ksigf2;nu;kappa)
0604
0605

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0606 !---CASE 6 : BRANCH 5 CZP UNCONTROLLED---!
0607 $scalp = PAR($Path6:($State6)$Bubran)
0608 voichg = FOR(voicold)
0609 tfuchg = FOR(tmocold)
0610 tmochg = FOR(tmocold)
0611 CASE = LIS('/Case6: CZP Uncontrolled'/E/f2:
voichg;voiref;tfuchg;tfuref;tmochg;tmoref)
0612
0613 bu = SEL(uburn/MAC/C1;$macALL2/$scalp)
0614 BURNUP = LIS('/Bundle Burnup'/E/f0:bu)
0615
0616 !---Surface ADFs---!
0617 jp = SEL(jp/CUR/ C1;Currents/$scalp)
0618 jm = SEL(jm/CUR/ C1;Currents/$scalp)
0619 fx = SEL(fx/MAC/ C1;$macALL2/$scalp)
0620 inorth = IND(jp/RAN:2;;;)
0621 ieast = IND(jp/RAN:5;;;)
0622 isouth = IND(jp/RAN:7;;;)
0623 iwest = IND(jp/RAN:4;;;)
0624 Sides = FOR(2*(jp+jm)/fx)
0625 adfN = FOR(Sides^inorth)
0626 adfE = FOR(Sides^ieast)
0627 adfS = FOR(Sides^isouth)
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0628 adfW = FOR(Sides^iwest)
0629 ADF = LIS(;;9/'ADFs'/E/f0:bu;e5:adfN;adfE;adfS;adfW)
0630
0631 !---Fission Product Yields---!
0632 nd = SEL(nd/MIC/C1;$micALL/$scalp)
0633 nI = SEL(nd/MIC/C1;$micALL/$scalp/53635)
0634 iIa = IND(nI/RAN:;;1,1,3,3,5,5,7,7,9,9,11,11,13,13,15,15,17,17,
0635 19,19,21,21,23,23,25,25,27,27,29,29,31,31,33,33,
0636 35,35,37,37,39,39,41,41,43,43,45,45,47,47,49,49,51,51;;)
0637 iIb = IND(nI/RAN:;;2,2,4,4,6,6,8,8,10,10,12,12,14,14,16,16,18,18,
0638 20,20,22,22,24,24,26,26,28,28,30,30,32,32,34,34,36,36,
0639 38,38,40,40,42,42,44,44,46,46,48,48,50,50,52,52;;)
0640 amult = FOR((nI^iIb)/(nI^iIa))
0641 nXe = SEL(nd/MIC/C1;$micALL/$scalp/54635)
0642 nPm = SEL(nd/MIC/C1;$micALL/$scalp/61649)
0643 aI = SEL(ab/MIC/C1;$micALL/$scalp/53635)
0644 aXe = SEL(ab/MIC/C1;$micALL/$scalp/54635)
0645 aPm = SEL(ab/MIC/C1;$micALL/$scalp/61649)
0646 fx = SEL(fx/MIC/C1;$micALL/$scalp)
0647 fi = SEL(fi/MIC/C1;$micALL/$scalp)
0648 vo = SEL(vo/MIC/C1;$micALL/$scalp)
0649 fimac = FOR(@smI(nd*fi))
0650 avfxfi = FOR(@smR(fx*fimac*vo)/@smR(vo))
0651 avfxaI = FOR(@smR(fx*aI*vo)/@smR(vo))
0652 avfxaXe = FOR(@smR(fx*aXe*vo)/@smR(vo))
0653 avfxaPm = FOR(@smR(fx*aPm*vo)/@smR(vo))
0654 'N(I)' = FOR(@smR(nI*vo)/@smR(vo))
0655 'N(Xe)' = FOR(@smR(nXe*vo)/@smR(vo))
0656 'N(Pm)' = FOR(@smR(nPm*vo)/@smR(vo))
0657 $lambdaI = PAR(2.875E-5) !--- lambda : unit=cm-1 ---!
0658 $lambdaXe = PAR(2.092E-5)
0659 $lambdaPm = PAR(3.556E-6)
0660 'Yield(I)' = FOR(1E24*'N(I)'*$lambdaI/avfxfi)
0661 'Yield(Xe)' = FOR(1E24*'N(Xe)'+(avfxaXe*1E-24+$lambdaXe)/avfxfi-'Yield(I)')
0662 'Yield(Pm)' = FOR(1E24*'N(Pm)'+$lambdaPm/avfxfi*amult)

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0663 FPYIELDS = LIS('/FPYIELDS'/E/f0:bu; e5:'Yield(I)';'Yield(Xe)';'Yield(Pm)')
0664
0665 !---Xenon Samarium---!
0666 micxe = SEL(ab/MIC/C1;$micALL2/$scalp/54635)
0667 ndxe = SEL(nd/MIC/C1;$micALL2/$scalp/54635)
0668 macxe = FOR(micxe*ndxe)
0669 micsm = SEL(ab/MIC/C1;$micALL2/$scalp/62649)
0670 ndsm = SEL(nd/MIC/C1;$micALL2/$scalp/62649)
0671 macsm = FOR(micsm*ndsm)
0672 XESM = LIS('/XESM'/E/f0:bu; e5: micxe;macxe;micsm;macsm)
0673
0674 !---kinf,prel,ppblr---!
0675 kinf = SEL(kinf /MAC/C1;$macALL2/$scalp)
0676 fx = SEL(fx/MAC/C1;$macPin/$scalp)
0677 kf = SEL(kf/MAC/C1;$macPin/$scalp)
0678 vo = SEL(vo/MAC/C1;$macPin/$scalp)
0679 vx = SEL(vx/MAC/C1;$macPin/$scalp)
0680 vy = SEL(vy/MAC/C1;$macPin/$scalp)
0681 bupin = SEL(bu/MAC/C1;$macPin/$scalp)
0682 Power = FOR(fx*kf*vo)
0683 AvePower = FOR((@smR(Power*vo))/@smR(vo))
0684 PP = FOR(Power/AvePower)
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0685 prel = FOR(@mxR(PP))
0686 ppblr = FOR(@mxR(bupin))
0687 PINTOBOX = LIS('/PINTOBOX'/E/f0:bu; f5:kinf;prel;ppblr)
0688
0689 !---Macro XS---!
0690 dr = SEL(dr/MAC/C1;$macALL2/$scalp)
0691 tr = SEL(tr/MAC/C1;$macALL2/$scalp)
0692 ab = SEL(ab/MAC/C1;$macALL2/$scalp)
0693 nf = SEL(nf/MAC/C1;$macALL2/$scalp)
0694 kf = SEL(kf/MAC/C1;$macALL2/$scalp)
0695 p0 = SEL(p0/MAC/C1;$macALL2/$scalp)
0696 fx = SEL(fx/MAC/C1;$macALL2/$scalp)
0697 i12 = IND(p0/RAN;;;2;1)
0698 i21 = IND(p0/RAN;;;1;2)
0699 i1 = IND(nf/RAN;;;1;)
0700 i2 = IND(nf/RAN;;;2;)
0701 diff = FOR(dr/(3.0*tr))
0702 d1 = FOR(diff^i1)
0703 d2 = FOR(diff^i2)
0704 s12 = FOR(p0^i12)
0705 s21 = FOR(p0^i21)
0706 fx1 = FOR(fx^i1)
0707 fx2 = FOR(fx^i2)
0708 s12net = FOR(s12-s21*fx2/fx1)
0709 ab1 = FOR(ab^i1)
0710 ab2 = FOR(ab^i2)
0711 nsigf1 = FOR(nf^i1)
0712 nsigf2 = FOR(nf^i2)
0713 ksigf1 = FOR(kf^i1)
0714 ksigf2 = FOR(kf^i2)
0715 nf = SEL(nf/MAC/C1;$macALL/$scalp)
0716 kf = SEL(kf/MAC/C1;$macALL/$scalp)
0717 fi = SEL(fi/MAC/C1;$macALL/$scalp)
0718 nu = FOR(nf/fi)
0719 kappa = FOR(kf/fi)
0720 'MACRO-FAST' = LIS('/MACRO-FAST'/E/f0:bu; e5: d1;s12net;ab1;nsigf1;ksigf1)

```

```

0721 'MACRO-THERMAL' = LIS('/MACRO-THERMAL'/E/f0:bu; e5: d2;ab2;nsigf2;ksigf2;nu;kappa)
0722
0723 !---CASE 7 : BRANCH 6 CZP CONTROLLED---!
0724 $scalp = PAR($Path7:($State7)$Bubran)
0725 voichg = FOR(voicold)
0726 tfuchg = FOR(tmocold)
0727 tmochg = FOR(tmocold)
0728 CASE = LIS('/Case7: CZP Controlled'/E/f2:
voichg;voiref;tfuchg;tfuref;tmochg;tmoref)
0729
0730 bu = SEL(uburn/MAC/C1;$macALL2/$scalp)
0731 BURNUP = LIS('/Bundle Burnup'/E/f0:bu)
0732
0733 !---Surface ADFs---!
0734 jp = SEL(jp/CUR/ C1;Currents/$scalp)
0735 jm = SEL(jm/CUR/ C1;Currents/$scalp)
0736 fx = SEL(fx/MAC/ C1;$macALL2/$scalp)
0737 inorth = IND(jp/RAN:2;;;)
0738 ieast = IND(jp/RAN:5;;;)
0739 isouth = IND(jp/RAN:7;;;)
0740 iwest = IND(jp/RAN:4;;;)
0741 Sides = FOR(2*(jp+jm)/fx)
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0742 adfN = FOR(Sides^inorth)
0743 adfE = FOR(Sides^ieast)
0744 adfS = FOR(Sides^isouth)
0745 adfW = FOR(Sides^iwest)
0746 ADF = LIS(;;9/'ADFs'/E/f0:bu;e5:adfN;adfE;adfS;adfW)
0747
0748 !---Fission Product Yields---!
0749 nd = SEL(nd/MIC/C1;$micALL/$scalp)
0750 nI = SEL(nd/MIC/C1;$micALL/$scalp/53635)
0751 iIa = IND(nI/RAN:;;1,1,3,3,5,5,7,7,9,9,11,11,13,13,15,15,17,17,
0752 19,19,21,21,23,23,25,25,27,27,29,29,31,31,33,33,
0753 35,35,37,37,39,39,41,41,43,43,45,45,47,47,49,49,51,51;;)
0754 iIb = IND(nI/RAN:;;2,2,4,4,6,6,8,8,10,10,12,12,14,14,16,16,18,18,
0755 20,20,22,22,24,24,26,26,28,28,30,30,32,32,34,34,36,36,
0756 38,38,40,40,42,42,44,44,46,46,48,48,50,50,52,52;;)
0757 amult = FOR((nI^iIb)/(nI^iIa))
0758 nXe = SEL(nd/MIC/C1;$micALL/$scalp/54635)
0759 nPm = SEL(nd/MIC/C1;$micALL/$scalp/61649)
0760 aI = SEL(ab/MIC/C1;$micALL/$scalp/53635)
0761 aXe = SEL(ab/MIC/C1;$micALL/$scalp/54635)
0762 aPm = SEL(ab/MIC/C1;$micALL/$scalp/61649)
0763 fx = SEL(fx/MIC/C1;$micALL/$scalp)
0764 fi = SEL(fi/MIC/C1;$micALL/$scalp)
0765 vo = SEL(vo/MIC/C1;$micALL/$scalp)
0766 fimac = FOR(@smI(nd*fi))
0767 avfxfi = FOR(@smR(fx*fimac*vo)/@smR(vo))
0768 avfxaI = FOR(@smR(fx*aI*vo)/@smR(vo))
0769 avfxaXe = FOR(@smR(fx*aXe*vo)/@smR(vo))
0770 avfxaPm = FOR(@smR(fx*aPm*vo)/@smR(vo))
0771 'N(I)' = FOR(@smR(nI*vo)/@smR(vo))
0772 'N(Xe)' = FOR(@smR(nXe*vo)/@smR(vo))
0773 'N(Pm)' = FOR(@smR(nPm*vo)/@smR(vo))
0774 $lambdaI = PAR(2.875E-5) !--- lambda : unit=cm-1 ---!
0775 $lambdaXe = PAR(2.092E-5)
0776 $lambdaPm = PAR(3.556E-6)
0777 'Yield(I)' = FOR(1E24*'N(I)')*$lambdaI/avfxfi)

```

```

0778 'Yield(Xe)'= FOR(1E24*'N(Xe)')*(avfxaXe*1E-24+$lambdaXe)/avfxfi-'Yield(I)')
0779 'Yield(Pm)'= FOR(1E24*'N(Pm)')*$lambdaPm/avfxfi*amult)
0780 FPYIELDS = LIS('/'FPYIELDS'/E/f0:bu; e5:'Yield(I)';'Yield(Xe)';'Yield(Pm)')
0781
0782 !---Xenon Samarium---!
0783 micxe = SEL(ab/MIC/C1;$micALL2/$scalp/54635)
0784 ndxe = SEL(nd/MIC/C1;$micALL2/$scalp/54635)
0785 macxe = FOR(micxe*ndxe)
0786 micsm = SEL(ab/MIC/C1;$micALL2/$scalp/62649)
0787 ndsm = SEL(nd/MIC/C1;$micALL2/$scalp/62649)
0788 macsm = FOR(micsm*ndsm)
0789 XESM = LIS('/'XESM'/E/f0:bu; e5: micxe;macxe;micsm;macsm)
0790
0791 !---kinf,prel,ppblr---!
0792 kinf = SEL(kinf /MAC/C1;$macALL2/$scalp)
0793 fx = SEL(fx/MAC/C1;$macPin/$scalp)
0794 kf = SEL(kf/MAC/C1;$macPin/$scalp)
0795 vo = SEL(vo/MAC/C1;$macPin/$scalp)
0796 vx = SEL(vx/MAC/C1;$macPin/$scalp)
0797 vy = SEL(vy/MAC/C1;$macPin/$scalp)
0798 bupin = SEL(bu/MAC/C1;$macPin/$scalp)

```

```

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```

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```

0799 Power = FOR(fx*kf*vo)
0800 AvePower = FOR((@smR(Power*vo))/@smR(vo))
0801 PP = FOR(Power/AvePower)
0802 prel = FOR(@mxR(PP))
0803 ppblr = FOR(@mxR(bupin))
0804 PINTOBOX = LIS('/'PINTOBOX'/E/f0:bu; f5:kinf;prel;ppblr)
0805
0806 !---Macro XS---!
0807 dr = SEL(dr/MAC/C1;$macALL2/$scalp)
0808 tr = SEL(tr/MAC/C1;$macALL2/$scalp)
0809 ab = SEL(ab/MAC/C1;$macALL2/$scalp)
0810 nf = SEL(nf/MAC/C1;$macALL2/$scalp)
0811 kf = SEL(kf/MAC/C1;$macALL2/$scalp)
0812 p0 = SEL(p0/MAC/C1;$macALL2/$scalp)
0813 fx = SEL(fx/MAC/C1;$macALL2/$scalp)
0814 i12 = IND(p0/RAN;;;2;1)
0815 i21 = IND(p0/RAN;;;1;2)
0816 i1 = IND(nf/RAN;;;1;)
0817 i2 = IND(nf/RAN;;;2;)
0818 diff = FOR(dr/(3.0*tr))
0819 d1 = FOR(diff^i1)
0820 d2 = FOR(diff^i2)
0821 s12 = FOR(p0^i12)
0822 s21 = FOR(p0^i21)
0823 fx1 = FOR(fx^i1)
0824 fx2 = FOR(fx^i2)
0825 s12net = FOR(s12-s21*fx2/fx1)
0826 ab1 = FOR(ab^i1)
0827 ab2 = FOR(ab^i2)
0828 nsigf1 = FOR(nf^i1)
0829 nsigf2 = FOR(nf^i2)
0830 ksigf1 = FOR(kf^i1)
0831 ksigf2 = FOR(kf^i2)
0832 nf = SEL(nf/MAC/C1;$macALL/$scalp)
0833 kf = SEL(kf/MAC/C1;$macALL/$scalp)
0834 fi = SEL(fi/MAC/C1;$macALL/$scalp)
0835 nu = FOR(nf/fi)

```

```

0836 kappa      = FOR(kf/fi)
0837 'MACRO-FAST' = LIS('/MACRO-FAST'/E/f0:bu; e5: d1;s12net;ab1;nsigf1;ksigf1)
0838 'MACRO-THERMAL' = LIS('/MACRO-THERMAL'/E/f0:bu; e5: d2;ab2;nsigf2;ksigf2;nu;kappa)
0839
0840 END()

```

A3. FORCIP-B Input File

FORCIP-B is an interface code which reads and processes cross sections from the lattice physics code's outputs, the output of FORCIP-B utilized as input to the FORMOSA-B code. The FORCIP-B code has been modified to read HELIOS/ZENITH outputs. For the complete documentation on the FORCIP-B input file, please refer to [4].

```

'COM'
'COM' 'FORCIP-B V1'
'COM'
'FCP.OUT','forcipb.table'/
'FCP.TIT','GE-11 MOX Bundle UO2-Alike Cross Sections'/
'FCP.PRT',1,0,1,0,31*1,32*1/
'COM'
'COM' FCP.OPT(1)=control rod history opt, FCP.OPT(2)=buckling opt,
'COM' FCP.OPT(3)=BOC CRH correction opt. FCP.OPT(4)=EPF option
'COM' FCP.OPT(5)=Reflector cards
'FCP.OPT',1,0,1,0,1/
'FCP.TYP',9,3/
'COM'
'STA'
'TYP.NUM',1,1/
'TYP.NBP',0,3/
'TFU.PCT', 5, 0.932, 2.795, 5.204, 8.384, 13.973/
'TFU.CFT', 5, 608.78, 708.25, 840.70,1022.05,1358.92,'DEGK'/
'TFU.BRN', 8, 0.00, 5.00, 10.00, 15.00, 20.00, 30.00, 40.00, 50.00/
'TFU.DEL',8,0.00, -32.30, -53.90, -73.00, -91.30,-104.00,-103.20,-102.80,'DEGK'/
'CHG.VOI',3,0.,40.,70./
'CHG.FUE',2,792.5,560./
'CHG.ROD',2,0.,1./
'CHG.CZP',2,560.,293./
'CAS.STA'
'CAS.ENR',4.22/
'CAS.GCC',1,2.24784/
'CAS.VOL',1,1.000/
'CAS.NOM','zlower00.out','* '//
'CAS.NOM','zlower40.out','* '//
'CAS.NOM','zlower70.out','* '//
'CAS.CRH','zlower40CRH.out','* '//
'COM'
'TYP.NUM',2,1/
'TYP.NBP',0,3/
'TFU.PCT', 5, 0.932, 2.795, 5.204, 8.384, 13.973/

```

```

'TFU.CFT',      5, 608.78, 708.25, 840.70,1022.05,1358.92,'DEGK'/
'TFU.BRN',      8,   0.00,   5.00,  10.00,  15.00,  20.00,  30.00,  40.00,  50.00/
'TFU.DEL',      8,0.00, -32.30, -53.90, -73.00, -91.30,-104.00,-103.20,-102.80,'DEGK'/
'CHG.VOI',      3,0.,40.,70./
'CHG.FUE',      2,792.5,560./
'CHG.ROD',      2,0.,1./
'CHG.CZP',      2,560.,293./
'CAS.STA'
'CAS.ENR',4.22/
'CAS.GCC',1,2.24784/
'CAS.VOL',1,1.000/
'CAS.NOM','zmiddle00.out','*  '/
'CAS.NOM','zmiddle40.out','*  '/
'CAS.NOM','zmiddle70.out','*  '/
'CAS.CRH','zmiddle40CRH.out','*  '/
'COM'
'TYP.NUM',3,1/
'TYP.NBP',0,3/
'TFU.PCT',      5, 0.932, 2.795, 5.204, 8.384, 13.973/
'TFU.CFT',      5, 608.78, 708.25, 840.70,1022.05,1358.92,'DEGK'/
'TFU.BRN',      8,   0.00,   5.00,  10.00,  15.00,  20.00,  30.00,  40.00,  50.00/
'TFU.DEL',      8,0.00, -32.30, -53.90, -73.00, -91.30,-104.00,-103.20,-102.80,'DEGK'/
'CHG.VOI',      3,0.,40.,70./
'CHG.FUE',      2,792.5,560./
'CHG.ROD',      2,0.,1./
'CHG.CZP',      2,560.,293./
'CAS.STA'
'CAS.ENR',4.50/
'CAS.GCC',1,2.00485/
'CAS.VOL',1,1.000/
'CAS.NOM','zupper00.out','*  '/
'CAS.NOM','zupper40.out','*  '/
'CAS.NOM','zupper70.out','*  '/
'CAS.CRH','zupper40CRH.out','*  '/
'COM'
'TYP.NUM',4,1/
'TYP.NBP',0,3/
'TFU.PCT',      5, 0.932, 2.795, 5.204, 8.384, 13.973/
'TFU.CFT',      5, 608.78, 708.25, 840.70,1022.05,1358.92,'DEGK'/
'TFU.BRN',      8,   0.00,   5.00,  10.00,  15.00,  20.00,  30.00,  40.00,  50.00/
'TFU.DEL',      8,0.00, -32.30, -53.90, -73.00, -91.30,-104.00,-103.20,-102.80,'DEGK'/
'CHG.VOI',      3,0.,40.,70./
'CHG.FUE',      2,792.5,560./
'CHG.ROD',      2,0.,1./
'CHG.CZP',      2,560.,293./
'CAS.STA'
'CAS.ENR',3.52027/
'CAS.GCC',1,2.24793/
'CAS.VOL',1,1.000/
'CAS.NOM','zlleulower00.out','*  '/
'CAS.NOM','zlleulower40.out','*  '/
'CAS.NOM','zlleulower70.out','*  '/
'CAS.CRH','zlleulower40CRH.out','*  '/
'COM'
'TYP.NUM',5,1/
'TYP.NBP',0,3/

```

```

'TFU.PCT',    5,  0.932,  2.795,  5.204,  8.384, 13.973/
'TFU.CFT',    5, 608.78, 708.25, 840.70,1022.05,1358.92,'DEGK'/
'TFU.BRN',    8,   0.00,   5.00,  10.00,  15.00,  20.00,  30.00,  40.00,  50.00/
'TFU.DEL',    8,0.00, -32.30, -53.90, -73.00, -91.30,-104.00,-103.20,-102.80,'DEGK'/
'CHG.VOI',    3,0.,40.,70./
'CHG.FUE',    2,792.5,560./
'CHG.ROD',    2,0.,1./
'CHG.CZP',    2,560.,293./
'CAS.STA'
'CAS.ENR',    3.690/
'CAS.GCC',    1,2.24793/
'CAS.VOL',    1,1.000/
'CAS.NOM',    'zlleumiddle00.out','*  '/
'CAS.NOM',    'zlleumiddle40.out','*  '/
'CAS.NOM',    'zlleumiddle70.out','*  '/
'CAS.CRH',    'zlleumiddle40CRH.out','*  '/
'COM'
'TYP.NUM',    6,1/
'TYP.NBP',    0,3/
'TFU.PCT',    5,  0.932,  2.795,  5.204,  8.384, 13.973/
'TFU.CFT',    5, 608.78, 708.25, 840.70,1022.05,1358.92,'DEGK'/
'TFU.BRN',    8,   0.00,   5.00,  10.00,  15.00,  20.00,  30.00,  40.00,  50.00/
'TFU.DEL',    8,0.00, -32.30, -53.90, -73.00, -91.30,-104.00,-103.20,-102.80,'DEGK'/
'CHG.VOI',    3,0.,40.,70./
'CHG.FUE',    2,792.5,560./
'CHG.ROD',    2,0.,1./
'CHG.CZP',    2,560.,293./
'CAS.STA'
'CAS.ENR',    3.880/
'CAS.GCC',    1,2.00491/
'CAS.VOL',    1,1.000/
'CAS.NOM',    'zlleuupper00.out','*  '/
'CAS.NOM',    'zlleuupper40.out','*  '/
'CAS.NOM',    'zlleuupper70.out','*  '/
'CAS.CRH',    'zlleuupper40CRH.out','*  '/
'COM'
'TYP.NUM',    7,1/
'TYP.NBP',    0,3/
'TFU.PCT',    5,  0.932,  2.795,  5.204,  8.384, 13.973/
'TFU.CFT',    5, 608.78, 708.25, 840.70,1022.05,1358.92,'DEGK'/
'TFU.BRN',    8,   0.00,   5.00,  10.00,  15.00,  20.00,  30.00,  40.00,  50.00/
'TFU.DEL',    8,0.00, -32.30, -53.90, -73.00, -91.30,-104.00,-103.20,-102.80,'DEGK'/
'CHG.VOI',    3,0.,40.,70./
'CHG.FUE',    2,792.5,560./
'CHG.ROD',    2,0.,1./
'CHG.CZP',    2,560.,293./
'CAS.STA'
'CAS.ENR',    3.82027/
'CAS.GCC',    1,2.24793/
'CAS.VOL',    1,1.000/
'CAS.NOM',    'zhleulower00.out','*  '/
'CAS.NOM',    'zhleulower40.out','*  '/
'CAS.NOM',    'zhleulower70.out','*  '/
'CAS.CRH',    'zhleulower40CRH.out','*  '/
'COM'
'TYP.NUM',    8,1/

```

```

'TYP.NBP',0,3/
'TFU.PCT',5,0.932, 2.795, 5.204, 8.384, 13.973/
'TFU.CFT',5,608.78, 708.25, 840.70,1022.05,1358.92,'DEGK'/
'TFU.BRN',8,0.00, 5.00, 10.00, 15.00, 20.00, 30.00, 40.00, 50.00/
'TFU.DEL',8,0.00, -32.30, -53.90, -73.00, -91.30,-104.00,-103.20,-102.80,'DEGK'/
'CHG.VOI',3,0.,40.,70./
'CHG.FUE',2,792.5,560./
'CHG.ROD',2,0.,1./
'CHG.CZP',2,560.,293./
'CAS.STA'
'CAS.ENR',3.990/
'CAS.GCC',1,2.24793/
'CAS.VOL',1,1.000/
'CAS.NOM','zhleumiddle00.out','* '/'
'CAS.NOM','zhleumiddle40.out','* '/'
'CAS.NOM','zhleumiddle70.out','* '/'
'CAS.CRH','zhleumiddle40CRH.out','* '/'
'COM'
'TYP.NUM',9,1/
'TYP.NBP',0,3/
'TFU.PCT', 5, 0.932, 2.795, 5.204, 8.384, 13.973/
'TFU.CFT', 5, 608.78, 708.25, 840.70,1022.05,1358.92,'DEGK'/
'TFU.BRN', 8, 0.00, 5.00, 10.00, 15.00, 20.00, 30.00, 40.00, 50.00/
'TFU.DEL',8,0.00, -32.30, -53.90, -73.00, -91.30,-104.00,-103.20,-102.80,'DEGK'/
'CHG.VOI',3,0.,40.,70./
'CHG.FUE',2,792.5,560./
'CHG.ROD',2,0.,1./
'CHG.CZP',2,560.,293./
'CAS.STA'
'CAS.ENR',4.180/
'CAS.GCC',1,2.00491/
'CAS.VOL',1,1.000/
'CAS.NOM','zhleuupper00.out','* '/'
'CAS.NOM','zhleuupper40.out','* '/'
'CAS.NOM','zhleuupper70.out','* '/'
'CAS.CRH','zhleuupper40CRH.out','* '/'
'COM'
'TYP.REF',1/
'REF.HXS',1,'RFH ',1,1,0/
'REF.WFR',.890/
'REF.VOI',1,0./
'REF.CVO',1,0./
'REF.FUE',2,815.,293./
'REF.CZP',2,560.,293./
'REF.XSC','bwrref.cax'/
'REF.XSC','rrefcld.cax'/
'TYP.REF',2/
'REF.HXS',1,'RFH ',1,1,1/
'REF.WFR',.890/
'REF.VOI',1,0./
'REF.CVO',1,0./
'REF.FUE',2,815.,293./
'REF.CZP',2,560.,293./
'REF.XSC','bwrbbref.cax'/
'REF.XSC','brefcld.cax'/
'TYP.REF',3/

```

```

'REF.HXS',1,'RFH ',1,1,1/
'REF.WFR',.890/
'REF.VOI',3,0.,40.,70./
'REF.CVO',1,0./
'REF.FUE',2,815.,293./
'REF.CZP',2,560.,293./
'REF.XSC','bwrtref0.cax'/
'REF.XSC','bwrtref4.cax'/
'REF.XSC','bwrtref7.cax'/
'REF.XSC','trefcld.cax'/
'END'
/EOF

```

A4. FORMOSA-B Sample Input File

The following is a sample of the FORMOSA-B standard input file for the equilibrium cycle, full MOX core. For complete documentation on the FORMOSA-B standard input file, please refer to [5].

```

'FOR.TIT' 'Grand Gulf NS Equilibrium Cycle Full MOX Core with GE-11 Bundles'
'COM'      [nemflg][lthfb][lcrhfb][lprfb][icrit][jdebug]
'FOR.CON'  1      2      1      0      1      2
'COM'      [nass][isymm][ibc][nref][ibuflag][ipit][nmtype][nbwide]
'FOR.GEO'  800    2      0      1      1      0      1      32
'COM'      [icore][icsymm][irist][ilimx][ilist][hrefuel]
'FOR.ROD'  0      2      0      -1      0      14000.0
'COM'      [idosdm][ncrpsdm][ (irodsdm(j),j=1,ncrpsdm)]
'FOR.SDM'  0      1      1
'COM'      [ihtby][iflim][ferr]
'FOR.FL1'  0      10     0.10E-02
'COM'      [istmtab][ivoidfit]
'FOR.FL2'  0      2
'COM'      [ispcrvoi][cutoff][ipolyfit][spvfile]
'FOR.FL3'  2      0.001    1      'eqcycfullmox.cyc'
'COM'      [...5.....10.....15.....20.....25.....30]
'FOR.PT1'  2 0 2 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
'FOR.PT2'  0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0
'COM'      [isch][krnge][gptlim][isopt][ishuf][igpt][nobj][nfreq][ierflag]
'OPT.CON'  1 .180 0.100E-02 0 2 0 1 3 0
'COM'      [iaq][nbtreg][kexcess][flpdlim][ratlim][flcprlim][cor8lim]
'OPT.LIM'  1      1      0.08  0.9  0.9  0.9  0.50
'COM'      [ibq][sdmlim][pinlim][asslim][nreglim][ (irpt,reglim(i),i=1,nreglim)]
'OPT.XLM'  1      0.038 56000.0 45000.0 1 6 40000.0
'COM'      [npsfl][ (psflo(i),i=1,npsfl)][ (psfhi(i),i=1,npsfl)]
'OPT.PSR'  6 6*0.0 6*2.0
'COM'      [narc][nbin][archhigh][arclow][dishi][dislo][mcseed]
'OPT.ARC'  25     8      1.000 0.8500 0.0030 0.0010 2711
'COM'      [nplam][ (plam(i) i=1,npfcst)]
'OPT.PEN'  23 23*1.0

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'COM'      [nfresh] [nbadis] [(nrdis(i),nbdis(i),i=1,nbadis)]
'OPT.DBU'   264      2      1      2      2      1
'COM'      [fthid(2)]
'FUL.MEC'   'eqcycfullmox.cyc' 'IMECH_TYPE_1'
'COM'      [idum] [numreg] [numbat] [fileidxs(1)] [fileidxs(2)] [idsubl] [idsubu]
'FUL.IDS'   1  2  1  'eqcycfullmox.cyc' '6 53-286 11-286 11-386 53-38' 0 0
'FUL.IDS'   2  2  1  'eqcycfullmox.cyc' '6 51-266 13-266 13-406 51-40' 0 0
'FUL.IDS'   3  2  1  'eqcycfullmox.cyc' '6 35-146 29-146 29-526 35-52' 0 0
'FUL.IDS'   4  2  1  'eqcycfullmox.cyc' '6 37-166 27-166 27-506 37-50' 0 0
'FUL.IDS'   5  2  1  'eqcycfullmox.cyc' '6 51-306 13-306 13-366 51-36' 0 0
'FUL.IDS'   6  2  1  'eqcycfullmox.cyc' '6 51-186 13-186 13-486 51-48' 0 0
'FUL.IDS'   7  2  1  'eqcycfullmox.cyc' '6 49-286 15-286 15-386 49-38' 0 0
'FUL.IDS'   8  2  1  'eqcycfullmox.cyc' '6 49-166 15-166 15-506 49-50' 0 0
'FUL.IDS'   9  2  1  'eqcycfullmox.cyc' '6 53-246 11-246 11-426 53-42' 0 0
'FUL.IDS'  10  2  1  'eqcycfullmox.cyc' '6 47-146 17-146 17-526 47-52' 0 0
'FUL.IDS'  11  2  1  'eqcycfullmox.cyc' '6 39-146 25-146 25-526 39-52' 0 0
'FUL.IDS'  12  2  1  'eqcycfullmox.cyc' '6 43-146 21-146 21-526 43-52' 0 0
'FUL.IDS'  13  2  1  'eqcycfullmox.cyc' '6 37-126 27-126 27-546 37-54' 0 0
'FUL.IDS'  14  1  2  'eqcycfullmox.cyc' '5 61-325 3-325 3-345 61-34' 0 0
'FUL.IDS'  15  1  2  'eqcycfullmox.cyc' '5 33-045 31-045 31-625 33-62' 0 0
'FUL.IDS'  16  2  1  'eqcycfullmox.cyc' '6 51-226 13-226 13-446 51-44' 0 0
'FUL.IDS'  17  2  1  'eqcycfullmox.cyc' '6 47-266 17-266 17-406 47-40' 0 0
'FUL.IDS'  18  2  1  'eqcycfullmox.cyc' '6 47-226 17-226 17-446 47-44' 0 0
'FUL.IDS'  19  2  1  'eqcycfullmox.cyc' '6 49-246 15-246 15-426 49-42' 0 0
'FUL.IDS'  20  2  1  'eqcycfullmox.cyc' '6 41-126 23-126 23-546 41-54' 0 0
'FUL.IDS'  21  2  1  'eqcycfullmox.cyc' '6 41-166 23-166 23-506 41-50' 0 0
'FUL.IDS'  22  2  1  'eqcycfullmox.cyc' '6 43-186 21-186 21-486 43-48' 0 0
'FUL.IDS'  23  2  1  'eqcycfullmox.cyc' '6 43-266 21-266 21-406 43-40' 0 0
'FUL.IDS'  24  2  1  'eqcycfullmox.cyc' '6 39-186 25-186 25-486 39-48' 0 0
'FUL.IDS'  25  2  1  'eqcycfullmox.cyc' '6 53-166 11-166 11-506 53-50' 0 0
'FUL.IDS'  26  2  1  'eqcycfullmox.cyc' '6 53-326 11-326 11-346 53-34' 0 0
'FUL.IDS'  27  2  1  'eqcycfullmox.cyc' '6 53-206 11-206 11-466 53-46' 0 0
'FUL.IDS'  28  2  1  'eqcycfullmox.cyc' '6 41-086 23-086 23-586 41-58' 0 0
'FUL.IDS'  29  2  1  'eqcycfullmox.cyc' '6 55-226 9-226 9-446 55-44' 0 0
'FUL.IDS'  30  2  1  'eqcycfullmox.cyc' '6 33-126 31-126 31-546 33-54' 0 0
'FUL.IDS'  31  2  1  'eqcycfullmox.cyc' '6 43-226 21-226 21-446 43-44' 0 0
'FUL.IDS'  32  2  1  'eqcycfullmox.cyc' '6 49-126 15-126 15-546 49-54' 0 0
'FUL.IDS'  33  2  1  'eqcycfullmox.cyc' '6 39-226 25-226 25-446 39-44' 0 0
'FUL.IDS'  34  2  1  'eqcycfullmox.cyc' '6 45-126 19-126 19-546 45-54' 0 0
'FUL.IDS'  35  2  1  'eqcycfullmox.cyc' '6 49-326 15-326 15-346 49-34' 0 0
'FUL.IDS'  36  2  1  'eqcycfullmox.cyc' '6 51-146 13-146 13-526 51-52' 0 0
'FUL.IDS'  37  2  1  'eqcycfullmox.cyc' '6 47-306 17-306 17-366 47-36' 0 0
'FUL.IDS'  38  2  1  'eqcycfullmox.cyc' '6 43-106 21-106 21-566 43-56' 0 0
'FUL.IDS'  39  2  1  'eqcycfullmox.cyc' '6 57-246 7-246 7-426 57-42' 0 0
'FUL.IDS'  40  2  1  'eqcycfullmox.cyc' '6 35-306 29-306 29-366 35-36' 0 0
'FUL.IDS'  41  2  1  'eqcycfullmox.cyc' '6 35-186 29-186 29-486 35-48' 0 0
'FUL.IDS'  42  2  1  'eqcycfullmox.cyc' '6 57-286 7-286 7-386 57-38' 0 0
'FUL.IDS'  43  2  1  'eqcycfullmox.cyc' '6 33-086 31-086 31-586 33-58' 0 0
'FUL.IDS'  44  2  1  'eqcycfullmox.cyc' '6 33-166 31-166 31-506 33-50' 0 0
'FUL.IDS'  45  2  1  'eqcycfullmox.cyc' '6 39-266 25-266 25-406 39-40' 0 0
'FUL.IDS'  46  2  1  'eqcycfullmox.cyc' '6 57-326 7-326 7-346 57-34' 0 0
'FUL.IDS'  47  2  1  'eqcycfullmox.cyc' '6 37-086 27-086 27-586 37-58' 0 0
'FUL.IDS'  48  2  1  'eqcycfullmox.cyc' '6 45-166 19-166 19-506 45-50' 0 0
'FUL.IDS'  49  2  1  'eqcycfullmox.cyc' '6 49-206 15-206 15-466 49-46' 0 0
'FUL.IDS'  50  2  1  'eqcycfullmox.cyc' '6 35-226 29-226 29-446 35-44' 0 0
'FUL.IDS'  51  2  1  'eqcycfullmox.cyc' '6 43-306 21-306 21-366 43-36' 0 0

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'FUL.IDS'	52	2	1	'eqcycfullmox.cyc'	'6	53-126	11-126	11-546	53-54'	0	0
'FUL.IDS'	53	2	1	'eqcycfullmox.cyc'	'6	47-186	17-186	17-486	47-48'	0	0
'FUL.IDS'	54	2	1	'eqcycfullmox.cyc'	'6	55-266	9-266	9-406	55-40'	0	0
'FUL.IDS'	55	2	1	'eqcycfullmox.cyc'	'6	45-206	19-206	19-466	45-46'	0	0
'FUL.IDS'	56	2	1	'eqcycfullmox.cyc'	'6	39-106	25-106	25-566	39-56'	0	0
'FUL.IDS'	57	2	1	'eqcycfullmox.cyc'	'6	35-266	29-266	29-406	35-40'	0	0
'FUL.IDS'	58	2	1	'eqcycfullmox.cyc'	'6	55-306	9-306	9-366	55-36'	0	0
'FUL.IDS'	59	2	1	'eqcycfullmox.cyc'	'6	35-106	29-106	29-566	35-56'	0	0
'FUL.IDS'	60	2	1	'eqcycfullmox.cyc'	'6	39-306	25-306	25-366	39-36'	0	0
'FUL.IDS'	61	2	1	'eqcycfullmox.cyc'	'6	47-106	17-106	17-566	47-56'	0	0
'FUL.IDS'	62	2	1	'eqcycfullmox.cyc'	'6	55-186	9-186	9-486	55-48'	0	0
'FUL.IDS'	63	3	1	'eqcycfullmox.cyc'	'7	43-227	21-227	21-447	43-44'	0	0
'FUL.IDS'	64	3	1	'eqcycfullmox.cyc'	'7	45-207	19-207	19-467	45-46'	0	0
'FUL.IDS'	65	2	1	'eqcycfullmox.cyc'	'6	57-206	7-206	7-466	57-46'	0	0
'FUL.IDS'	66	2	1	'eqcycfullmox.cyc'	'6	59-306	5-306	5-366	59-36'	0	0
'FUL.IDS'	67	2	1	'eqcycfullmox.cyc'	'6	45-086	19-086	19-586	45-58'	0	0
'FUL.IDS'	68	2	1	'eqcycfullmox.cyc'	'6	35-066	29-066	29-606	35-60'	0	0
'FUL.IDS'	69	3	1	'eqcycfullmox.cyc'	'7	39-227	25-227	25-447	39-44'	0	0
'FUL.IDS'	70	3	1	'eqcycfullmox.cyc'	'7	49-207	15-207	15-467	49-46'	0	0
'FUL.IDS'	71	3	1	'eqcycfullmox.cyc'	'7	39-147	25-147	25-527	39-52'	0	0
'FUL.IDS'	72	3	1	'eqcycfullmox.cyc'	'7	41-127	23-127	23-547	41-54'	0	0
'FUL.IDS'	73	3	1	'eqcycfullmox.cyc'	'7	47-227	17-227	17-447	47-44'	0	0
'FUL.IDS'	74	3	1	'eqcycfullmox.cyc'	'7	39-267	25-267	25-407	39-40'	0	0
'FUL.IDS'	75	3	1	'eqcycfullmox.cyc'	'7	33-047	31-047	31-627	33-62'	0	0
'FUL.IDS'	76	3	1	'eqcycfullmox.cyc'	'7	61-327	3-327	3-347	61-34'	0	0
'FUL.IDS'	77	2	2	'eqcycfullmox.cyc'	'6	61-326	3-326	3-346	61-34'	0	0
'FUL.IDS'	78	3	1	'eqcycfullmox.cyc'	'7	43-267	21-267	21-407	43-40'	0	0
'FUL.IDS'	79	2	2	'eqcycfullmox.cyc'	'6	33-046	31-046	31-626	33-62'	0	0
'FUL.IDS'	80	3	1	'eqcycfullmox.cyc'	'7	49-167	15-167	15-507	49-50'	0	0
'FUL.IDS'	81	3	1	'eqcycfullmox.cyc'	'7	51-267	13-267	13-407	51-40'	0	0
'FUL.IDS'	82	3	1	'eqcycfullmox.cyc'	'7	45-167	19-167	19-507	45-50'	0	0
'FUL.IDS'	83	3	1	'eqcycfullmox.cyc'	'7	47-187	17-187	17-487	47-48'	0	0
'FUL.IDS'	84	3	1	'eqcycfullmox.cyc'	'7	35-267	29-267	29-407	35-40'	0	0
'FUL.IDS'	85	3	1	'eqcycfullmox.cyc'	'7	35-307	29-307	29-367	35-36'	0	0
'FUL.IDS'	86	3	1	'eqcycfullmox.cyc'	'7	47-147	17-147	17-527	47-52'	0	0
'FUL.IDS'	87	3	1	'eqcycfullmox.cyc'	'7	51-227	13-227	13-447	51-44'	0	0
'FUL.IDS'	88	3	1	'eqcycfullmox.cyc'	'7	53-247	11-247	11-427	53-42'	0	0
'FUL.IDS'	89	3	1	'eqcycfullmox.cyc'	'7	49-247	15-247	15-427	49-42'	0	0
'FUL.IDS'	90	3	1	'eqcycfullmox.cyc'	'7	39-307	25-307	25-367	39-36'	0	0
'FUL.IDS'	91	3	1	'eqcycfullmox.cyc'	'7	49-287	15-287	15-387	49-38'	0	0
'FUL.IDS'	92	3	1	'eqcycfullmox.cyc'	'7	51-187	13-187	13-487	51-48'	0	0
'FUL.IDS'	93	3	1	'eqcycfullmox.cyc'	'7	53-287	11-287	11-387	53-38'	0	0
'FUL.IDS'	94	3	1	'eqcycfullmox.cyc'	'7	47-267	17-267	17-407	47-40'	0	0
'FUL.IDS'	95	3	1	'eqcycfullmox.cyc'	'7	43-147	21-147	21-527	43-52'	0	0
'FUL.IDS'	96	3	1	'eqcycfullmox.cyc'	'7	41-167	23-167	23-507	41-50'	0	0
'FUL.IDS'	97	3	1	'eqcycfullmox.cyc'	'7	51-307	13-307	13-367	51-36'	0	0
'FUL.IDS'	98	3	1	'eqcycfullmox.cyc'	'7	37-167	27-167	27-507	37-50'	0	0
'FUL.IDS'	99	3	1	'eqcycfullmox.cyc'	'7	49-327	15-327	15-347	49-34'	0	0
'FUL.IDS'	100	3	1	'eqcycfullmox.cyc'	'7	53-207	11-207	11-467	53-46'	0	0
'FUL.IDS'	101	3	1	'eqcycfullmox.cyc'	'7	45-127	19-127	19-547	45-54'	0	0
'FUL.IDS'	102	3	1	'eqcycfullmox.cyc'	'7	39-187	25-187	25-487	39-48'	0	0
'FUL.IDS'	103	3	1	'eqcycfullmox.cyc'	'7	35-147	29-147	29-527	35-52'	0	0
'FUL.IDS'	104	3	1	'eqcycfullmox.cyc'	'7	37-127	27-127	27-547	37-54'	0	0
'FUL.IDS'	105	3	1	'eqcycfullmox.cyc'	'7	43-187	21-187	21-487	43-48'	0	0
'FUL.IDS'	106	3	1	'eqcycfullmox.cyc'	'7	55-267	9-267	9-407	55-40'	0	0
'FUL.IDS'	107	3	1	'eqcycfullmox.cyc'	'7	47-307	17-307	17-367	47-36'	0	0

'FUL.IDS'108	3	1	'eqcycfullmox.cyc'	'7	33-167	31-167	31-507	33-50'	0	0
'FUL.IDS'109	3	1	'eqcycfullmox.cyc'	'7	53-327	11-327	11-347	53-34'	0	0
'FUL.IDS'110	3	1	'eqcycfullmox.cyc'	'7	35-187	29-187	29-487	35-48'	0	0
'FUL.IDS'111	3	1	'eqcycfullmox.cyc'	'7	55-307	9-307	9-367	55-36'	0	0
'FUL.IDS'112	3	1	'eqcycfullmox.cyc'	'7	51-147	13-147	13-527	51-52'	0	0
'FUL.IDS'113	3	1	'eqcycfullmox.cyc'	'7	55-227	9-227	9-447	55-44'	0	0
'FUL.IDS'114	3	1	'eqcycfullmox.cyc'	'7	33-127	31-127	31-547	33-54'	0	0
'FUL.IDS'115	3	1	'eqcycfullmox.cyc'	'7	39-107	25-107	25-567	39-56'	0	0
'FUL.IDS'116	3	1	'eqcycfullmox.cyc'	'7	35-107	29-107	29-567	35-56'	0	0
'FUL.IDS'117	3	1	'eqcycfullmox.cyc'	'7	35-227	29-227	29-447	35-44'	0	0
'FUL.IDS'118	3	1	'eqcycfullmox.cyc'	'7	43-107	21-107	21-567	43-56'	0	0
'FUL.IDS'119	3	1	'eqcycfullmox.cyc'	'7	49-127	15-127	15-547	49-54'	0	0
'FUL.IDS'120	3	1	'eqcycfullmox.cyc'	'7	53-167	11-167	11-507	53-50'	0	0
'FUL.IDS'121	3	1	'eqcycfullmox.cyc'	'7	53-127	11-127	11-547	53-54'	0	0
'FUL.IDS'122	3	1	'eqcycfullmox.cyc'	'7	43-307	21-307	21-367	43-36'	0	0
'FUL.IDS'123	3	1	'eqcycfullmox.cyc'	'7	57-327	7-327	7-347	57-34'	0	0
'FUL.IDS'124	3	1	'eqcycfullmox.cyc'	'7	35-067	29-067	29-607	35-60'	0	0
'FUL.IDS'125	3	1	'eqcycfullmox.cyc'	'7	33-087	31-087	31-587	33-58'	0	0
'FUL.IDS'126	3	1	'eqcycfullmox.cyc'	'7	57-287	7-287	7-387	57-38'	0	0
'FUL.IDS'127	3	1	'eqcycfullmox.cyc'	'7	59-307	5-307	5-367	59-36'	0	0
'FUL.IDS'128	3	1	'eqcycfullmox.cyc'	'7	47-107	17-107	17-567	47-56'	0	0
'FUL.IDS'129	3	1	'eqcycfullmox.cyc'	'7	37-087	27-087	27-587	37-58'	0	0
'FUL.IDS'130	3	1	'eqcycfullmox.cyc'	'7	55-187	9-187	9-487	55-48'	0	0
'FUL.IDS'131	3	1	'eqcycfullmox.cyc'	'7	45-087	19-087	19-587	45-58'	0	0
'FUL.IDS'132	3	1	'eqcycfullmox.cyc'	'7	57-207	7-207	7-467	57-46'	0	0
'FUL.IDS'133	3	1	'eqcycfullmox.cyc'	'7	57-247	7-247	7-427	57-42'	0	0
'FUL.IDS'134	3	1	'eqcycfullmox.cyc'	'7	41-087	23-087	23-587	41-58'	0	0
'FUL.IDS'135	4	1	'eqcycfullmox.cyc'	'LYV573LYV572LYV570LYV571-MOX'	0	0				

'MAP.FLP'

52 73113 89112 81120 19135 26135 35135122135 7
105135 27135 18135 46135 36135 49135 60135127 14
118 34 74 87123 94126 80135 92135 99135 65 16
96135 95135 37135 42135 29135 51135 62106 6
85 22125 41121 91133 88135 97135100135 64 8
71135102135 98135 39135 25135 54135 66111 23
119 43129 47134 28135 93135 78135107135132 1
21135 63135 72135104135 55135 58135130 5
135 40135 38135 32135 53135109135 70 2
30135 86135103135 69135114135 77 90 17
135 48135 50135 56135 59135 79135 76 9
44135108135101135110135 82 84 75 45
135 57135 61135 68135128 11 24 20
117135 67115 83116131 3
135124 12 10 31 33 13

4 15

'MAP.SLP', Initial Fuel Subshade Pattern (fixed-format)

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0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0


```

2 2
'MAP.FFX', Restricted Shuffling Locations Array (fixed-format)
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0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 0
0 0 0 0 0 0 0 0 1 0 1 0 1 0 0
0 1 0 1 0 1 0 1 0 1 0 1 0 0 0
0 0 0 0 0 0 0 0 1 0 1 0 1 0 0
0 1 0 1 0 1 0 1 0 1 0 1 0 0 0
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0 1 0 1 0 1 0 1 0 1 0 1 0 0
1 0 1 0 1 0 1 0 1 0 1 0 0
0 1 0 1 0 1 0 1 0 1 0 0 0
1 0 1 0 1 0 1 0 1 0 1 0 0
0 1 0 1 0 1 0 1 0 0 0 0
1 0 1 0 1 0 1 0 0 0 0
0 1 0 0 0 0 0 0
1 0 0 0 0 0 0
0 0

'COM', Radial Reflector XS IDs
'REF.RAD' 1
'COM', Axial Reflector Mappings
'REF.AXR' 1 2
'REF.MAP', Axial Reflector Map (fixed-format)
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2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
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2 2 2 2 2 2 2 2 2 2 2 2 2
2 2 2 2 2 2 2 2 2 2 2 2
2 2 2 2 2 2 2 2 2 2 2
2 2 2 2 2 2 2 2 2 2
2 2 2 2 2 2 2 2 2
2 2 2 2 2 2 2 2
2 2
'REF.MAP', Axial Reflector Map (fixed-format)
3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
3 3 3 3 3 3 3 3 3 3 3 3 3 3
3 3 3 3 3 3 3 3 3 3 3 3 3
3 3 3 3 3 3 3 3 3 3 3 3
3 3 3 3 3 3 3 3 3 3 3
3 3 3 3 3 3 3 3 3 3
3 3 3 3 3 3 3 3 3
3 3 3 3 3 3 3 3
3 3

```

```

'COM'      [Control Rod Programming Options]
'COM'      [Number of Active CRP Groups]
'ROD.GRP'  4
'COM'      [Number of Active CRP Subgroups in Each Group]
'ROD.SGP'  8 9 8 8
'COM'      [GRP][SGP][Notch Number Selections]
'COM'      (optional cards)
'ROD.NNS'  1 1 24 28 12 40 08
'ROD.NNS'  1 2 24 28 12 40 08
'ROD.NNS'  1 3 24 28 12 40 08
'ROD.NNS'  1 4 24 28 12 40 08
'ROD.NNS'  1 5 24 28 12 40 08
'ROD.NNS'  1 6 24 28 12 40 08
'ROD.NNS'  1 7 24 28 12 40 08
'ROD.NNS'  1 8 24 28 12 40 08
'ROD.NNS'  2 1 24 28 12 40 08
'ROD.NNS'  2 2 24 28 12 40 08
'ROD.NNS'  2 3 24 28 12 40 08
'ROD.NNS'  2 4 24 28 12 40 08
'ROD.NNS'  2 5 24 28 12 40 08
'ROD.NNS'  2 6 24 28 12 40 08
'ROD.NNS'  2 7 24 28 12 40 08
'ROD.NNS'  2 8 24 28 12 40 08
'ROD.NNS'  2 9 24 28 12 40 08
'ROD.NNS'  3 1 24 28 12 40 08
'ROD.NNS'  3 2 24 28 12 40 08
'ROD.NNS'  3 3 24 28 12 40 08
'ROD.NNS'  3 4 24 28 12 40 08
'ROD.NNS'  3 5 24 28 12 40 08
'ROD.NNS'  3 6 24 28 12 40 08
'ROD.NNS'  3 7 24 28 12 40 08
'ROD.NNS'  3 8 24 28 12 40 08
'ROD.NNS'  4 1 24 28 12 40 08
'ROD.NNS'  4 2 24 28 12 40 08
'ROD.NNS'  4 3 24 28 12 40 08
'ROD.NNS'  4 4 24 28 12 40 08
'ROD.NNS'  4 5 24 28 12 40 08
'ROD.NNS'  4 6 24 28 12 40 08
'ROD.NNS'  4 7 24 28 12 40 08
'ROD.NNS'  4 8 24 28 12 40 08
'COM'      [GRP][SGP][Number of Deep Notches Selected]
'COM'      (only one entry needed, rest are OPTIONAL)
'ROD.DEE'  1 1 12
'ROD.DEE'  1 2 12
'ROD.DEE'  1 3 12
'ROD.DEE'  1 4 12
'ROD.DEE'  1 5 12
'ROD.DEE'  1 7 12
'ROD.DEE'  1 7 12
'ROD.DEE'  1 8 12
'ROD.DEE'  2 1 12
'ROD.DEE'  2 2 12
'ROD.DEE'  2 3 12
'ROD.DEE'  2 4 12
'ROD.DEE'  2 5 12
'ROD.DEE'  2 6 12

```

```

'ROD.DEE' 2      7      12
'ROD.DEE' 2      8      12
'ROD.DEE' 2      9      12
'ROD.DEE' 3      1      12
'ROD.DEE' 3      2      12
'ROD.DEE' 3      3      12
'ROD.DEE' 3      4      12
'ROD.DEE' 3      5      12
'ROD.DEE' 3      6      12
'ROD.DEE' 3      7      12
'ROD.DEE' 3      8      12
'ROD.DEE' 4      1      12
'ROD.DEE' 4      2      12
'ROD.DEE' 4      3      12
'ROD.DEE' 4      4      12
'ROD.DEE' 4      5      12
'ROD.DEE' 4      6      12
'ROD.DEE' 4      7      12
'ROD.DEE' 4      8      12
'COM'          [GRP][SGP][Deep Notch Numbers]
'COM'          (only one entry needed, rest are OPTIONAL)
'ROD.DNN' 1      1      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 1      2      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 1      3      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 1      4      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 1      5      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 1      6      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 1      7      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 1      8      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 2      1      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 2      2      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 2      3      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 2      4      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 2      5      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 2      6      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 2      7      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 2      8      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 2      9      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 3      1      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 3      2      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 3      3      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 3      4      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 3      5      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 3      6      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 3      7      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 3      8      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 4      1      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 4      2      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 4      3      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 4      4      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 4      5      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 4      6      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 4      7      0 4 6 8 10 12 14 16 18 20 22 24
'ROD.DNN' 4      8      0 4 6 8 10 12 14 16 18 20 22 24
'COM'          [GRP][SGP][Number of Shallow Notches Selected]
'COM'          (only one entry needed, rest are OPTIONAL)

```

'ROD.SHA'	1	1	13
'ROD.SHA'	1	2	13
'ROD.SHA'	1	3	13
'ROD.SHA'	1	4	13
'ROD.SHA'	1	5	13
'ROD.SHA'	1	6	13
'ROD.SHA'	1	7	13
'ROD.SHA'	1	8	13
'ROD.SHA'	2	1	13
'ROD.SHA'	2	2	13
'ROD.SHA'	2	3	13
'ROD.SHA'	2	4	13
'ROD.SHA'	2	5	13
'ROD.SHA'	2	6	13
'ROD.SHA'	2	7	13
'ROD.SHA'	2	8	13
'ROD.SHA'	2	9	13
'ROD.SHA'	3	1	13
'ROD.SHA'	3	2	13
'ROD.SHA'	3	3	13
'ROD.SHA'	3	4	13
'ROD.SHA'	3	5	13
'ROD.SHA'	3	6	13
'ROD.SHA'	3	7	13
'ROD.SHA'	3	8	13
'ROD.SHA'	4	1	13
'ROD.SHA'	4	2	13
'ROD.SHA'	4	3	13
'ROD.SHA'	4	4	13
'ROD.SHA'	4	5	13
'ROD.SHA'	4	6	13
'ROD.SHA'	4	7	13
'ROD.SHA'	4	8	13
'COM'	[GRP][SGP][Shallow Notch Numbers]		
'COM'	(optional cards)		
'ROD.SNN'	1	1	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	1	2	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	1	3	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	1	4	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	1	5	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	1	6	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	1	7	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	1	8	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	2	1	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	2	2	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	2	3	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	2	4	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	2	5	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	2	6	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	2	7	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	2	8	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	2	9	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	3	1	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	3	2	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	3	3	24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN'	3	4	24 26 28 30 32 34 36 38 40 42 44 46 48


```

'ROD.SNN' 3 5 24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN' 3 6 24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN' 3 7 24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN' 3 8 24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN' 4 1 24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN' 4 2 24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN' 4 3 24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN' 4 4 24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN' 4 5 24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN' 4 6 24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN' 4 7 24 26 28 30 32 34 36 38 40 42 44 46 48
'ROD.SNN' 4 8 24 26 28 30 32 34 36 38 40 42 44 46 48
'COM' [Control Rod Programming Bias Options (ALL OPTIONAL CARDS)]
'COM' [Bias on Active CRP Groups]
'COM' [klist()][klimx()](OPTIONAL CARD)]
'COM' klist(mxrlili) = OLI where ILI number changes
'COM' klimx(mxrlili) = number of ILI
'ROD.ILI' 1 -200
'ROD.ILI' 2 -200
'ROD.ILI' 3 -200
'ROD.ILI' 4 -200
'ROD.ILI' 5 -200
'ROD.ILI' 6 -200
'ROD.ILI' 7 -200
'ROD.ILI' 8 -200
'ROD.ILI' 9 -200
'ROD.ILI' 10 -200
'ROD.ILI' 11 -200
'ROD.ILI' 12 -200
'ROD.ILI' 13 -200
'ROD.ILI' 14 -200
'ROD.ILI' 15 -200
'COM' [Active Rod Map]
'ROD.MAP'
11 21 13 23 14 25 16 0
41 31 43 34 45 36 48 0
13 24 12 22 15 26 18 0
44 33 42 32 46 38 0 0
14 25 15 26 17 29 0
45 35 46 37 47 0 0
16 27 18 28 0 0
0 0 0 0
'COM', [Depletion and Control Rod Pattern]
'DEP.STP' 3833.00 93.76 1047.00 21.50 0.00 1 2 0 0.00000E+00
'DEP.TLM' 0.940 0.940 0.940
'DEP.CRP' 1 31 1.00000 0.850 1.000
14 48 8 48 18 48 48 48
48 48 48 48 48 48 48 48
8 48 10 48 28 48 48 48
48 48 48 48 48 48 48 48
18 48 28 48 44 48 48
48 48 48 48 48 48 48
48 48 48 48 48 48
48 48 48 48
'DEP.STP' 3833.00 94.15 1047.00 21.50 1500.00 1 3 0 0.00000E+00
'DEP.TLM' 0.940 0.940 0.940

```

'DEP.CRP'	2	34	1.00000	0.850	1.000				
48 48 48 48 48 48 48 48									
10 48 4 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 10 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 48									
'DEP.STP'	3833.00	94.03	1047.00	21.50	3000.00	1	3	0	0.00000E+00
'DEP.TLM'	0.940	0.940	0.940						
'DEP.CRP'	3	33	1.00000	0.850	1.000				
48 48 48 48 48 48 48 48									
48 8 48 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 12 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 48									
'DEP.STP'	3833.00	105.73	1047.00	21.50	4500.00	1	3	0	0.00000E+00
'DEP.TLM'	0.940	0.940	0.940						
'DEP.CRP'	4	32	1.00000	0.850	1.000				
48 6 48 10 48 48 48 48									
48 48 48 48 48 48 48 48									
48 8 48 10 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 48									
'DEP.STP'	3833.00	94.41	1047.00	21.50	6000.00	1	3	0	0.00000E+00
'DEP.TLM'	0.940	0.940	0.940						
'DEP.CRP'	5	31	1.00000	0.850	1.000				
30 48 48 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 12 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 48									
'DEP.STP'	3833.00	106.10	1047.00	21.50	7500.00	1	3	0	0.00000E+00
'DEP.TLM'	0.940	0.940	0.940						
'DEP.CRP'	6	34	1.00000	0.850	1.000				
48 48 48 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 8 48 10 48 48 48									
48 48 48 48 48 48 48 48									
48 48 10 48 48 48 48 48									
48 48 48 48 48 48 48 48									
48 48 48 48									
'DEP.STP'	3833.00	97.01	1047.00	21.50	9000.00	1	3	0	0.00000E+00
'DEP.TLM'	0.940	0.940	0.940						
'DEP.CRP'	7	33	1.00000	0.850	1.000				

```

48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 10 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48
48 48 48 48
'DEP.STP' 3833.00 98.48 1047.00 21.50 10500.00 1 3 0 0.00000E+00
'DEP.TLM' 0.940 0.940 0.940
'DEP.CRP' 8 32 1.00000 0.850 1.050
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48
'DEP.STP' 3833.00 106.75 1047.00 21.50 11500.00 1 3 0 0.00000E+00
'DEP.TLM' 0.940 0.940 0.940
'DEP.CRP' 9 31 1.00000 0.850 1.050
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48
'DEP.STP' 3833.00 117.01 1047.00 21.50 12350.00 1 3 0 0.00000E+00
'DEP.TLM' 0.940 0.940 0.940
'DEP.CRP' 10 0 1.00000 0.850 1.050
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48 48 48 48 48
48 48 48 48
'END'

```

A5. FORMOSA-B Sample Output File

Since the complete FORMOSA-B output file is very long, only part of this file for the equilibrium cycle, full MOX core is shown below. The complete FORMOSA-B output is available in /u10/fmdp2/GEBWR.DIR.

```
=====
* Output : General Results for Reference Pattern
=====

Input Symmetry Selected:
*** Quarter-Core Reflective Symmetry ***

Shuffling Symmetry Options Selected :
*** No Limitations ***
*** Averaging of BU Gradients To Be Performed ***

Optimization Selected :
*** EOC Flow Minimization ***

Constraints :

*** MLHGR on Peak Pin Basis (MFLPD) ***
*** MAPLHGR (MAPRAT) ***
*** MCPR (MFLCPR) ***
*** 8th-Core Power Balance ***
*** Peak Pin Discharge Burnup ***
*** Peak Assembly Discharge Burnup ***
*** Region Discharge Burnups ***
*** Region/Batch Power Sharing ***
*** EOC Criticality ***

Simulated Annealing Class :
>>> Global Search <<<

Optimization Cooling Cycle : 1 of 1
Debugging Flag : 2
Number of Change Cases : 0
Max. Allowed Change Cases : 15000
Number of Burnup Steps : 10
Allocated Burnup Steps : 12
```

```
Data for Burnup Time Step : 1 of 10
Accumulated Cycle Burnup (MWD/ST): 0.00
Percent Rated Core Power : 100.0000
Percent Rated Core Flow : 83.3422
k-effective (Non-Linear NEM) : 0.9999456
```

```

CRD Notches Inserted      :      642
Total Core Loading (MTU)   :    153.3893
Average Absolute Fast Flux :   2.0964E+14
Average Absolute Thermal Flux :  4.1605E+13
Fission Product Conditions : EqXe & PkSm
Thermal Hydraulic Conditions : T/H, Flow On

```

Reference Control Rod Pattern

```

14 -- 8 -- 18 -- -- --
-- -- -- -- --
8 -- 10 -- 28 -- -- --
-- -- -- -- --
18 -- 28 -- 44 -- --
-- -- -- -- --
-- -- -- -- --
-- -- -- --

```

EDIT: IPROPT[1] = 2

Assembly k-infinity Map (Reference LP / WITH Converged Feedbacks)

```

-----
33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63

32- 0.8974 1.0706 1.0905 0.9332 0.9365 1.0852 1.0930 0.8996 0.9135 1.0037 1.0155 1.0056 1.0172 1.1076 1.0274 1.0132
30- 1.0874 1.0093 0.9937 1.0104 0.9858 1.0097 0.9983 1.0127 1.0022 1.0144 1.0133 1.0151 1.0368 1.0210 1.1172 1.0132
28- 1.0905 0.9962 1.0681 1.0873 1.0921 1.0840 1.0923 1.0884 1.0130 1.0921 1.0132 1.0915 1.0168 1.0663 1.0036
26- 0.9352 1.0105 1.0882 0.8748 0.8704 1.0104 0.9986 0.9455 0.9353 1.0126 1.0111 1.0138 1.0423 1.1094 1.0068
24- 0.9301 0.9883 1.0925 0.8718 0.9435 1.0865 1.0933 1.0221 0.9461 1.0904 1.0122 1.0942 1.0169 1.0766 1.0090
22- 1.0723 1.0103 1.0864 1.0105 1.0886 1.0102 0.9946 1.0107 0.9924 1.0116 1.0201 1.0141 1.0593 1.1127 1.0194
20- 1.0947 0.9977 1.0935 1.0019 1.0939 0.9888 1.0100 1.0866 1.0105 1.0792 1.0127 1.0961 1.0198 1.1174 1.0073
18- 0.9020 1.0138 1.0577 0.9463 1.0095 1.0107 1.0885 0.9974 1.0040 1.0115 1.0284 1.0174 1.1132 1.0066
16- 0.9140 1.0037 1.0139 0.9394 0.9467 0.9987 1.0107 1.0015 0.9986 1.0922 1.0149 1.0857 0.9913
14- 1.0060 1.0146 1.0923 1.0129 1.0921 1.0120 1.0597 1.0117 1.0931 1.0140 1.0757 1.1006 1.0115
12- 1.0157 1.0128 1.0133 1.0110 1.0123 1.0234 1.0130 1.0307 1.0148 1.0767 1.0215 1.0974 1.0166
10- 1.0081 1.0152 1.0935 1.0137 1.0944 1.0139 1.0971 1.0169 1.1010 1.1001 1.0957 1.0232
08- 1.0173 1.0324 1.0167 1.0418 1.0164 1.0609 1.0194 1.1122 0.9999 1.0132 1.0211
06- 1.1077 1.0210 1.0666 1.1094 1.1052 1.1122 1.1163 0.9994
04- 1.0274 1.1161 1.0013 1.0073 1.0163 1.0221 1.0187
02- 1.0088 1.0140

```

EDIT: IPROPT[3] = 2

Bundle Average Exposure Map (GWD/STU) (NEM / Reference LP)

```

-----
33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63

32- 24.468 14.691 14.041 15.219 13.776 15.674 13.425 29.146 0.0000 28.735 0.0000 28.438 0.0000 15.138 0.0000 29.376
30- 15.283 0.0000 28.572 0.0000 27.994 0.0000 26.903 0.0000 28.083 0.0000 25.973 0.0000 23.587 0.0000 11.424 29.499
28- 13.860 28.151 13.300 15.425 13.199 15.189 13.184 15.096 0.0000 15.019 0.0000 14.384 0.0000 20.423 28.660

```

26- 15.002 0.0000 15.254 0.0000 28.422 0.0000 28.262 0.0000 27.764 0.0000 26.702 0.0000 22.708 14.519 29.986
 24- 13.548 28.594 12.996 28.200 10.806 15.644 12.836 15.253 0.0000 15.237 0.0000 14.641 0.0000 13.883 30.082
 22- 14.727 0.0000 14.908 0.0000 15.310 0.0000 27.152 0.0000 27.883 0.0000 25.043 0.0000 20.356 14.298 28.996
 20- 13.444 26.975 12.963 27.869 12.676 26.223 0.0000 15.228 0.0000 14.307 0.0000 15.357 0.0000 11.522 29.560
 18- 29.075 0.0000 13.476 0.0000 14.351 0.0000 14.860 0.0000 23.967 0.0000 24.094 0.0000 12.497 30.218
 16- 0.0000 28.061 0.0000 27.608 0.0000 28.492 0.0000 25.524 0.0000 14.602 0.0000 14.884 29.933
 14- 28.474 0.0000 15.055 0.0000 15.012 0.0000 13.336 0.0000 14.391 0.0000 17.804 13.474 29.714
 12- 0.0000 26.720 0.0000 26.698 0.0000 24.619 0.0000 23.750 0.0000 17.623 0.0000 9.0979 29.801
 10- 28.042 0.0000 14.317 0.0000 14.537 0.0000 15.244 0.0000 15.574 14.115 8.9668 26.753
 08- 0.0000 24.164 0.0000 22.713 0.0000 20.024 0.0000 12.539 29.599 29.399 28.693
 06- 15.364 0.0000 20.340 14.165 15.425 14.040 11.481 29.229
 04- 0.0000 11.254 28.832 29.668 28.253 28.006 29.671
 02- 28.302 29.408

EDIT: IPROPT[4] = 1

Bundle Average Relative Power Fraction Map
 (NEM / Reference LP)

	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63
32-	1.0278	1.3033	1.3201	1.0624	1.0610	1.2964	1.2815	0.9215	0.9187	0.9818	1.0467	0.9559	0.9713	0.9207	0.6857	0.3729
30-	1.3363	1.2762	1.1782	1.2320	1.1466	1.2505	1.1582	1.1636	1.0407	1.0941	1.0206	1.0436	0.9448	0.8566	0.6973	0.3581
28-	1.3374	1.1839	1.2969	1.2887	1.2929	1.3036	1.3103	1.2494	1.1523	1.1848	1.1128	1.1118	0.9834	0.8232	0.5507	
26-	1.0543	1.2322	1.2900	0.9951	0.9459	1.2339	1.1658	1.1057	1.0088	1.1495	1.0663	1.0801	0.9558	0.8499	0.5053	
24-	1.0400	1.1394	1.2914	0.9464	1.0485	1.2838	1.3112	1.1675	1.0762	1.2072	1.1369	1.1254	0.9757	0.8060	0.4701	
22-	1.2508	1.2348	1.2969	1.2299	1.2840	1.2334	1.1598	1.2170	1.1051	1.1652	1.0739	1.0618	0.9380	0.7994	0.4429	
20-	1.2488	1.1362	1.2951	1.1613	1.3073	1.1550	1.2281	1.2776	1.2002	1.2035	1.1082	1.0678	0.8859	0.7141	0.3878	
18-	0.9066	1.1296	1.1937	1.0890	1.1492	1.2175	1.2792	1.2018	1.1228	1.1502	1.0296	0.9542	0.8231	0.5017		
16-	0.9072	1.0247	1.1231	1.0000	1.0636	1.1048	1.1998	1.1112	1.1465	1.1633	1.0300	0.8990	0.5895			
14-	0.9752	1.0856	1.1747	1.1413	1.2028	1.1520	1.1763	1.1475	1.1652	1.0575	0.9650	0.8167	0.4852			
12-	1.0413	1.0129	1.1097	1.0624	1.1348	1.0744	1.0999	1.0345	1.0345	0.9694	0.8359	0.6780	0.3877			
10-	0.9546	1.0405	1.1131	1.0815	1.1294	1.0657	1.0740	0.9677	0.9254	0.8222	0.6786	0.4405				
08-	0.9694	0.9384	0.9859	0.9634	0.9864	0.9499	0.8949	0.8360	0.6090	0.4928	0.3945					
06-	0.9185	0.8569	0.8283	0.8736	0.8479	0.8149	0.7284	0.5077								
04-	0.6847	0.6974	0.5546	0.5182	0.5005	0.4625	0.4011									
02-	0.3689	0.3589														

EDIT: IPROPT[4] = 1

Nodal Relative Power Fractions
 (NEM / Reference LP)

	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63
26	0.5302	0.4684	0.4444	0.4542	0.4270	0.3899	0.3649	0.3979	0.3297	0.3168	0.2611	0.2575	0.2020	0.1746	0.1320	0.1025
25	0.8752	0.7864	0.7418	0.7747	0.7208	0.6540	0.6056	0.6236	0.5419	0.5325	0.4288	0.4265	0.3363	0.3066	0.2274	0.1706
24	1.1712	1.1507	1.0969	1.1498	1.0679	0.9748	0.8932	0.8206	0.7642	0.7181	0.6082	0.5710	0.4814	0.4495	0.3249	0.2180
23	1.3393	1.3546	1.3285	1.3692	1.3069	1.1758	1.1018	0.9546	0.9229	0.8327	0.7340	0.6636	0.5870	0.5456	0.3996	0.2527
22	1.4014	1.4059	1.3755	1.3599	1.3179	1.2311	1.1901	1.0418	1.0098	0.8973	0.7993	0.7188	0.6460	0.6038	0.4486	0.2842
21	1.4770	1.4946	1.4675	1.1209	1.1105	1.3296	1.3410	1.1396	1.1436	0.9822	0.9122	0.7905	0.7430	0.6879	0.5137	0.3046
20	1.4738	1.4691	1.4429	1.0655	1.0721	1.3540	1.4109	1.2081	1.2318	1.0405	0.9878	0.8444	0.8122	0.7533	0.5640	0.3273
19	1.3293	1.3827	1.3680	1.0238	1.0385	1.3286	1.4037	1.2449	1.2709	1.0744	1.0223	0.8815	0.8504	0.7960	0.5987	0.3536
18	1.0296	1.3461	1.3490	1.0276	1.0429	1.3572	1.4291	1.3183	1.3550	1.1481	1.1093	0.9627	0.9363	0.8665	0.6608	0.3882
17	0.9627	1.3335	1.3624	1.0460	1.0696	1.3970	1.4585	1.2902	1.3546	1.1879	1.1977	1.0354	1.0298	0.9445	0.7240	0.4111
16	0.9331	1.2993	1.3379	1.0358	1.0638	1.3810	1.4254	1.0041	1.0441	1.1790	1.2208	1.0773	1.0731	0.9898	0.7617	0.4307
15	0.9133	1.2668	1.3072	1.0199	1.0475	1.3520	1.3752	0.9329	0.9692	1.1596	1.2201	1.0972	1.0938	1.0186	0.7894	0.4497
14	0.9280	1.3053	1.3519	1.0513	1.0858	1.3907	1.4113	0.9292	0.9833	1.1668	1.2743	1.1336	1.1631	1.0838	0.8389	0.4584
13	0.9324	1.3156	1.3630	1.0610	1.0954	1.3952	1.4116	0.9230	0.9813	1.1636	1.2887	1.1493	1.1951	1.1209	0.8704	0.4685

12 0.9331 1.3111 1.3561 1.0621 1.0909 1.3805 1.3889 0.9149 0.9669 1.1526 1.2774 1.1523 1.2021 1.1388 0.8890 0.4792
11 0.9536 1.3520 1.3965 1.1012 1.1174 1.4099 1.4097 0.9200 0.9663 1.1462 1.2987 1.1668 1.2414 1.1807 0.9189 0.4819
10 0.9687 1.3816 1.4248 1.1256 1.1342 1.4283 1.4150 0.9119 0.9470 1.1295 1.2941 1.1722 1.2561 1.2050 0.9307 0.4810
9 0.9812 1.3982 1.4418 1.1382 1.1428 1.4387 1.4102 0.9011 0.9178 1.1082 1.2719 1.1710 1.2532 1.2145 0.9302 0.4780
8 1.0096 1.4523 1.4958 1.1802 1.1807 1.4852 1.4449 0.9022 0.9069 1.0974 1.2797 1.1860 1.2834 1.2544 0.9473 0.4766
7 1.0443 1.5363 1.5771 1.2413 1.2337 1.5609 1.5062 0.9043 0.8980 1.0804 1.3026 1.2062 1.3341 1.3138 0.9677 0.4705
6 1.0696 1.6164 1.6511 1.2885 1.2707 1.6345 1.5633 0.8989 0.8781 1.0508 1.3101 1.2154 1.3690 1.3561 0.9691 0.4590
5 1.0698 1.6652 1.6961 1.2907 1.2675 1.6869 1.5990 0.8786 0.8382 1.0051 1.2834 1.2008 1.3569 1.3446 0.9314 0.4350
4 1.0163 1.5933 1.6357 1.1937 1.1868 1.6443 1.5505 0.8215 0.7566 0.9427 1.1962 1.1451 1.2551 1.2299 0.8218 0.3928
3 0.8474 1.2291 1.2977 0.8976 0.9364 1.3231 1.2500 0.6973 0.6110 0.8388 0.9841 1.0017 0.9969 0.9353 0.6259 0.3307
2 0.5061 0.6687 0.6939 0.4824 0.4970 0.7064 0.6771 0.4581 0.3791 0.5943 0.6041 0.6707 0.5837 0.5029 0.3573 0.2185

26 0.4659 0.4432 0.4668 0.4180 0.4460 0.3753 0.3910 0.3343 0.3432 0.2826 0.2768 0.2295 0.2202 0.1675 0.1317 0.0985
25 0.7794 0.7207 0.7817 0.6828 0.6869 0.6112 0.6263 0.5446 0.5549 0.4636 0.4699 0.3800 0.3685 0.2845 0.2314 0.1785
24 1.1426 1.0273 1.0687 0.9770 0.9114 0.8773 0.8455 0.7780 0.7423 0.6619 0.6435 0.5445 0.5004 0.4106 0.3391 0.2354
23 1.3484 1.2196 1.2213 1.1621 1.0457 1.0534 0.9887 0.9440 0.8667 0.8036 0.7522 0.6626 0.5961 0.5048 0.4245 0.2739
22 1.4006 1.2721 1.2560 1.1978 1.0900 1.1165 1.0587 1.0252 0.9419 0.8775 0.8124 0.7266 0.6549 0.5608 0.4813 0.3045
21 1.4970 1.3760 1.3033 1.2805 1.1420 1.2321 1.1554 1.1635 1.0427 1.0044 0.9006 0.8355 0.7356 0.6457 0.5579 0.3251
20 1.5014 1.3858 1.2843 1.2791 1.1569 1.2752 1.2066 1.2434 1.1108 1.0847 0.9686 0.9110 0.7974 0.7075 0.6142 0.3450
19 1.4178 1.3156 1.2227 1.2300 1.1379 1.2566 1.2131 1.2608 1.1463 1.1178 1.0055 0.9486 0.8376 0.7436 0.6490 0.3653
18 1.3841 1.3200 1.2344 1.2586 1.1797 1.3097 1.2735 1.3347 1.2255 1.2061 1.0890 1.0392 0.9191 0.8182 0.6901 0.3946
17 1.3735 1.3427 1.2471 1.3033 1.2161 1.3733 1.3170 1.3949 1.2721 1.2912 1.1640 1.1376 0.9991 0.8986 0.7414 0.4131
16 1.3385 1.3166 1.2268 1.2935 1.2107 1.3690 1.3050 1.3782 1.2635 1.3047 1.1895 1.1770 1.0393 0.9400 0.7781 0.4282
15 1.3049 1.2843 1.2064 1.2702 1.1970 1.3439 1.2806 1.3394 1.2415 1.2922 1.1962 1.1909 1.0617 0.9644 0.8057 0.4423
14 1.3451 1.3334 1.2255 1.3208 1.2237 1.3962 1.3001 1.3783 1.2541 1.3427 1.2303 1.2599 1.1132 1.0272 0.8537 0.4464
13 1.3562 1.3467 1.2291 1.3337 1.2288 1.4036 1.2946 1.3759 1.2468 1.3495 1.2377 1.2860 1.1382 1.0607 0.8836 0.4511
12 1.3515 1.3386 1.2259 1.3242 1.2217 1.3824 1.2715 1.3434 1.2232 1.3259 1.2271 1.2831 1.1449 1.0744 0.9015 0.4555
11 1.3938 1.3818 1.2455 1.3628 1.2432 1.4093 1.2718 1.3445 1.2048 1.3349 1.2323 1.3162 1.1714 1.1129 0.9286 0.4514
10 1.4246 1.4039 1.2596 1.3803 1.2590 1.4160 1.2673 1.3262 1.1787 1.3189 1.2253 1.3232 1.1852 1.1292 0.9375 0.4445
9 1.4438 1.4095 1.2691 1.3826 1.2706 1.4097 1.2626 1.2988 1.1515 1.2889 1.2102 1.3122 1.1898 1.1305 0.9294 0.4351
8 1.4984 1.4558 1.2975 1.4252 1.3091 1.4488 1.2870 1.3116 1.1445 1.2935 1.2133 1.3362 1.2166 1.1600 0.9455 0.4270
7 1.5813 1.5312 1.3330 1.4960 1.3677 1.5226 1.3321 1.3480 1.1416 1.3160 1.2241 1.3826 1.2599 1.2029 0.9646 0.4148
6 1.6602 1.5969 1.3578 1.5554 1.4213 1.5920 1.3766 1.3739 1.1269 1.3239 1.2246 1.4155 1.2942 1.2273 0.9646 0.3993
5 1.7161 1.6223 1.3537 1.5692 1.4437 1.6247 1.4010 1.3625 1.0896 1.2959 1.2037 1.4058 1.2957 1.2035 0.9253 0.3756
4 1.6657 1.5348 1.2887 1.4704 1.3836 1.5424 1.3562 1.2691 1.0179 1.2027 1.1468 1.3097 1.2323 1.0962 0.8096 0.3442
3 1.3121 1.2184 1.1071 1.1586 1.1567 1.2208 1.1517 1.0167 0.8831 0.9785 1.0038 1.0527 1.0367 0.8543 0.6040 0.2976
2 0.7050 0.7067 0.7434 0.6683 0.7167 0.6999 0.7215 0.6000 0.6030 0.5906 0.6678 0.6241 0.6109 0.4906 0.3405 0.2054

26 0.4459 0.4678 0.4404 0.4173 0.3962 0.3789 0.3499 0.3290 0.2998 0.2786 0.2490 0.2302 0.1972 0.1728 0.1466
25 0.7426 0.7823 0.7419 0.6973 0.6584 0.6353 0.5812 0.5491 0.4906 0.4673 0.4111 0.3939 0.3323 0.3084 0.2432
24 1.0956 1.0679 1.0574 1.0315 0.9696 0.9347 0.8609 0.8169 0.7055 0.6953 0.5938 0.5874 0.4828 0.4535 0.3187
23 1.3244 1.2191 1.2347 1.2382 1.1841 1.1164 1.0615 1.0090 0.8624 0.8626 0.7279 0.7174 0.5939 0.5436 0.3759
22 1.3696 1.2530 1.2845 1.2917 1.2485 1.1816 1.1491 1.0958 0.9444 0.9451 0.8001 0.7854 0.6565 0.5950 0.4213
21 1.4659 1.3030 1.3765 1.3750 1.3574 1.2917 1.3028 1.2453 1.0830 1.0846 0.9234 0.8937 0.7570 0.6649 0.4567
20 1.4603 1.2878 1.3973 1.3733 1.3720 1.3327 1.3758 1.3280 1.1712 1.1715 1.0048 0.9686 0.8274 0.7154 0.4906
19 1.3891 1.2275 1.3366 1.3139 1.3203 1.3152 1.3746 1.3484 1.2034 1.2089 1.0429 1.0081 0.8642 0.7461 0.5223
18 1.3701 1.2403 1.3345 1.3219 1.3308 1.3576 1.4198 1.4144 1.2991 1.2889 1.1403 1.0908 0.9491 0.8076 0.5685
17 1.3850 1.2545 1.3642 1.3562 1.3752 1.4170 1.4898 1.4939 1.3993 1.3818 1.2464 1.1857 1.0423 0.8694 0.6008
16 1.3608 1.2342 1.3524 1.3487 1.3736 1.4214 1.4980 1.5076 1.4223 1.4133 1.2860 1.2358 1.0844 0.9030 0.6248
15 1.3299 1.2134 1.3286 1.3290 1.3548 1.4053 1.4805 1.4968 1.4174 1.4157 1.2953 1.2546 1.1048 0.9240 0.6461
14 1.3776 1.2339 1.3842 1.3747 1.4067 1.4549 1.5380 1.5488 1.4781 1.4747 1.3662 1.3265 1.1752 0.9668 0.6600
13 1.3903 1.2381 1.4006 1.3856 1.4156 1.4596 1.5375 1.5428 1.4778 1.4796 1.3855 1.3542 1.2070 0.9892 0.6719
12 1.3834 1.2345 1.3927 1.3763 1.3990 1.4369 1.4944 1.4846 1.4221 1.4442 1.3684 1.3517 1.2126 0.9988 0.6822
11 1.4253 1.2551 1.4356 1.4083 1.4272 1.4655 1.4906 1.4515 1.3943 1.4353 1.3893 1.3857 1.2516 1.0230 0.6877
10 1.4532 1.2694 1.4527 1.4269 1.4402 1.4715 1.4732 1.4069 1.3449 1.4099 1.3836 1.3987 1.2667 1.0365 0.6893
9 1.4677 1.2781 1.4406 1.4351 1.4418 1.4644 1.4531 1.3762 1.3021 1.3832 1.3632 1.3939 1.2652 1.0438 0.6889
8 1.5213 1.3070 1.4847 1.4770 1.4859 1.5056 1.4847 1.3878 1.3063 1.3927 1.3833 1.4286 1.2974 1.0672 0.6941
7 1.6026 1.3433 1.5618 1.5439 1.5638 1.5869 1.5544 1.4224 1.3344 1.4220 1.4301 1.4941 1.3512 1.0968 0.6960
6 1.6760 1.3680 1.6260 1.6020 1.6385 1.6687 1.6241 1.4486 1.3498 1.4406 1.4662 1.5517 1.3905 1.1151 0.6901
5 1.7204 1.3634 1.6385 1.6252 1.6792 1.7183 1.6650 1.4436 1.3260 1.4279 1.4610 1.5618 1.3837 1.1059 0.6692
4 1.6600 1.2983 1.5216 1.5515 1.5957 1.6356 1.5914 1.3694 1.2241 1.3525 1.3648 1.4496 1.2841 1.0470 0.6255
3 1.3166 1.1137 1.1719 1.2450 1.2220 1.2507 1.2333 1.1124 0.9749 1.1198 1.0942 1.1170 1.0180 0.8795 0.5394

2 0.7021 0.7442 0.6633 0.6729 0.6664 0.6823 0.6745 0.6071 0.5731 0.6235 0.6437 0.6305 0.5895 0.5062 0.3567

26 0.4624 0.4223 0.4187 0.4173 0.4389 0.3606 0.3707 0.3216 0.3323 0.2676 0.2665 0.2174 0.2019 0.1639 0.1369
25 0.7873 0.6888 0.6991 0.6895 0.7332 0.5906 0.6054 0.5290 0.5334 0.4403 0.4425 0.3632 0.3580 0.2891 0.2408
24 1.1624 0.9826 1.0332 0.9854 0.9917 0.8511 0.8245 0.7643 0.7194 0.6368 0.6061 0.5299 0.5241 0.4360 0.3196
23 1.3771 1.1657 1.2400 1.1850 1.1512 1.0312 0.9674 0.9363 0.8496 0.7827 0.7191 0.6548 0.6298 0.5481 0.3745
22 1.3616 1.2043 1.2943 1.2567 1.2198 1.1027 1.0400 1.0212 0.9333 0.8622 0.7878 0.7243 0.6888 0.6106 0.4165
21 1.1103 1.2850 1.3793 1.3009 1.2228 1.2168 1.1384 1.1694 1.0427 0.9973 0.8842 0.8398 0.7726 0.6958 0.4447
20 1.0561 1.2808 1.3773 1.0266 0.9676 1.2554 1.1908 1.2612 1.1233 1.0882 0.9551 0.9196 0.8313 0.7454 0.4695
19 1.0169 1.2319 1.3177 0.9477 0.9023 1.2331 1.2051 1.2934 1.1722 1.1294 0.9984 0.9590 0.8642 0.7730 0.4950
18 1.0213 1.2610 1.3249 0.9703 0.9323 1.2939 1.2830 1.3965 1.2778 1.2352 1.0948 1.0540 0.9388 0.8242 0.5332
17 1.0406 1.3065 1.3598 1.0086 0.9634 1.3734 1.3550 1.5104 1.3732 1.3517 1.1860 1.1600 1.0151 0.8846 0.5579
16 1.0317 1.2976 1.3526 1.0110 0.9708 1.3889 1.3760 1.5527 1.4184 1.3966 1.2268 1.2062 1.0524 0.9209 0.5782
15 1.0172 1.2754 1.3333 1.0031 0.9734 1.3802 1.3793 1.5667 1.4457 1.4085 1.2453 1.2244 1.0729 0.9447 0.5977
14 1.0503 1.3273 1.3803 1.0426 0.9933 1.4419 1.4155 1.6451 1.4933 1.4841 1.2936 1.3019 1.1228 0.9956 0.6056
13 1.0616 1.3415 1.3918 1.0533 0.9976 1.4491 1.4095 1.6544 1.4971 1.4939 1.3054 1.3315 1.1454 1.0236 0.6143
12 1.0641 1.3330 1.3828 1.0477 0.9933 1.4186 1.3624 1.5392 1.3988 1.4445 1.2903 1.3273 1.1497 1.0382 0.6244
11 1.1033 1.3718 1.4149 1.0704 0.9967 1.4279 1.3274 1.1727 1.0799 1.4247 1.2914 1.3626 1.1740 1.0699 0.6257
10 1.1241 1.3878 1.4328 1.0732 0.9926 1.4160 1.2879 1.0684 0.9795 1.3822 1.2836 1.3716 1.1873 1.0895 0.6251
9 1.1316 1.3876 1.4397 1.0651 0.9890 1.3950 1.2656 1.0277 0.9454 1.3456 1.2734 1.3642 1.1928 1.1014 0.6244
8 1.1707 1.4277 1.4803 1.0878 1.0021 1.4229 1.2798 1.0293 0.9373 1.3580 1.2918 1.3971 1.2192 1.1328 0.6245
7 1.2278 1.4954 1.5460 1.1236 1.0182 1.4855 1.3154 1.0465 0.9335 1.3981 1.3299 1.4583 1.2584 1.1695 0.6162
6 1.2683 1.5499 1.6011 1.1428 1.0224 1.5412 1.3470 1.0507 0.9192 1.4277 1.3628 1.5091 1.2879 1.1885 0.6003
5 1.2579 1.5545 1.6188 1.1175 0.9966 1.5518 1.3494 1.0186 0.8838 1.4157 1.3698 1.5159 1.2892 1.1701 0.5749
4 1.1473 1.4445 1.5386 1.0143 0.9204 1.4452 1.2797 0.9245 0.8094 1.3132 1.3136 1.4206 1.2325 1.0891 0.5364
3 0.8507 1.1305 1.2287 0.7831 0.7612 1.1271 1.0749 0.7200 0.6748 1.0437 1.1228 1.1322 1.0470 0.8682 0.4705
2 0.4562 0.6509 0.6628 0.4532 0.4975 0.6461 0.6942 0.4218 0.4457 0.6097 0.7169 0.6585 0.6387 0.4758 0.3269

26 0.4557 0.4538 0.3986 0.4390 0.3850 0.3559 0.3286 0.3156 0.2884 0.2653 0.2342 0.2126 0.1832 0.1587 0.1284
25 0.7818 0.7005 0.6617 0.7353 0.6463 0.5991 0.5480 0.5316 0.4760 0.4487 0.3887 0.3640 0.3125 0.2851 0.2234
24 1.1117 0.9268 0.9723 0.9961 0.9489 0.8925 0.8158 0.7963 0.6886 0.6727 0.5665 0.5508 0.4603 0.4276 0.2949
23 1.2987 1.0585 1.1861 1.1569 1.1711 1.0813 1.0157 0.9879 0.8465 0.8288 0.7001 0.6943 0.5732 0.5247 0.3459
22 1.2935 1.0987 1.2557 1.2251 1.2670 1.1554 1.1079 1.0805 0.9294 0.9094 0.7745 0.7705 0.6385 0.5828 0.3867
21 1.0765 1.1456 1.3650 1.2288 1.3500 1.2640 1.2669 1.2334 1.0733 1.0413 0.9001 0.8935 0.7394 0.6561 0.4127
20 1.0378 1.1535 1.3757 0.9724 1.0882 1.3015 1.3471 1.3252 1.1710 1.1301 0.9868 0.9752 0.8093 0.6988 0.4330
19 1.0112 1.1341 1.3227 0.9067 1.0151 1.2856 1.3587 1.3625 1.2175 1.1748 1.0290 1.0161 0.8448 0.7294 0.4559
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10 1.1295 1.3177 1.4073 1.3807 1.4426 1.4415 1.5005 1.4903 1.4965 1.3888 1.2372 1.1105 0.6365
9 1.1089 1.2882 1.3805 1.3425 1.4173 1.4160 1.4742 1.4877 1.5136 1.4011 1.2597 1.1133 0.6407
8 1.0987 1.2930 1.3894 1.3532 1.4374 1.4396 1.5086 1.5316 1.5728 1.4566 1.3108 1.1522 0.6496
7 1.0824 1.3153 1.4172 1.3910 1.4869 1.4948 1.5799 1.6097 1.6681 1.5450 1.3864 1.2038 0.6540
6 1.0525 1.3219 1.4324 1.4163 1.5291 1.5368 1.6370 1.6728 1.7549 1.6202 1.4502 1.2288 0.6475
5 1.0051 1.2904 1.4133 1.3982 1.5334 1.5267 1.6297 1.6716 1.7875 1.6340 1.4693 1.1901 0.6205
4 0.9400 1.1923 1.3301 1.2904 1.4393 1.4064 1.4757 1.5211 1.6553 1.5032 1.3866 1.0492 0.5649
3 0.8325 0.9653 1.0976 1.0224 1.1282 1.1022 1.1058 1.1560 1.2329 1.1422 1.0941 0.7699 0.4692
2 0.5858 0.5804 0.6102 0.5967 0.6201 0.6380 0.6145 0.6442 0.6446 0.6262 0.5722 0.4199 0.3030

26 0.2582 0.2736 0.2465 0.2641 0.2327 0.2391 0.2121 0.2100 0.1798 0.1653 0.1386 0.1135 0.0971
25 0.4241 0.4653 0.4070 0.4399 0.3865 0.4143 0.3551 0.3681 0.3049 0.2932 0.2400 0.2002 0.1686

24 0.6013 0.6388 0.5879 0.6033 0.5636 0.5874 0.5201 0.5285 0.4506 0.4500 0.3541 0.2949 0.2195
 23 0.7257 0.7477 0.7207 0.7160 0.6970 0.7017 0.6448 0.6354 0.5640 0.5623 0.4454 0.3730 0.2581
 22 0.7906 0.8084 0.7926 0.7851 0.7714 0.7667 0.7147 0.6979 0.6315 0.6250 0.5049 0.4300 0.2940
 21 0.9026 0.8954 0.9154 0.8825 0.8969 0.8626 0.8259 0.7895 0.7392 0.7180 0.5905 0.5072 0.3183
 20 0.9778 0.9574 0.9986 0.9535 0.9836 0.9316 0.9052 0.8562 0.8169 0.7839 0.6554 0.5689 0.3445
 19 1.0129 0.9943 1.0373 0.9966 1.0260 0.9725 0.9482 0.8960 0.8588 0.8196 0.6940 0.6074 0.3721
 18 1.1003 1.0794 1.1351 1.0928 1.1295 1.0664 1.0478 0.9845 0.9501 0.8925 0.7661 0.6471 0.4053
 17 1.1896 1.1551 1.2419 1.1847 1.2457 1.1610 1.1599 1.0746 1.0526 0.9739 0.8444 0.6986 0.4258
 16 1.2145 1.1822 1.2829 1.2261 1.2959 1.2050 1.2120 1.1193 1.1035 1.0166 0.8895 0.7394 0.4457
 15 1.2157 1.1913 1.2936 1.2457 1.3148 1.2265 1.2359 1.1444 1.1310 1.0419 0.9216 0.7741 0.4674
 14 1.2714 1.2256 1.3661 1.2946 1.3975 1.2841 1.3224 1.2058 1.2162 1.1096 0.9934 0.8357 0.4773
 13 1.2874 1.2340 1.3869 1.3074 1.4235 1.3040 1.3592 1.2358 1.2601 1.1466 1.0390 0.8798 0.4904
 12 1.2775 1.2252 1.3710 1.2930 1.4077 1.2966 1.3602 1.2430 1.2746 1.1615 1.0654 0.9105 0.5059
 11 1.2995 1.2300 1.3926 1.2937 1.4293 1.3124 1.4028 1.2764 1.3291 1.2071 1.1161 0.9519 0.5139
 10 1.2950 1.2224 1.3868 1.2854 1.4258 1.3157 1.4170 1.2971 1.3584 1.2399 1.1410 0.9607 0.5138
 9 1.2723 1.2064 1.3655 1.2734 1.4086 1.3141 1.4130 1.3101 1.3701 1.2644 1.1480 0.9375 0.5090
 8 1.2788 1.2071 1.3841 1.2891 1.4368 1.3423 1.4530 1.3515 1.4220 1.3175 1.1867 0.9546 0.5054
 7 1.2994 1.2132 1.4286 1.3223 1.4967 1.3917 1.5250 1.4136 1.5027 1.3956 1.2408 0.9764 0.4952
 6 1.3038 1.2080 1.4618 1.3498 1.5473 1.4349 1.5842 1.4671 1.5684 1.4642 1.2713 0.9727 0.4776
 5 1.2740 1.1819 1.4540 1.3509 1.5558 1.4463 1.5904 1.4819 1.5759 1.4896 1.2409 0.9197 0.4459
 4 1.1854 1.1226 1.3567 1.2919 1.4610 1.3839 1.4766 1.4100 1.4555 1.4106 1.1095 0.7889 0.3954
 3 0.9751 0.9867 1.0879 1.1058 1.1611 1.1667 1.1521 1.1663 1.1207 1.1080 0.8375 0.5826 0.3282
 2 0.5993 0.6704 0.6413 0.7136 0.6750 0.7317 0.6608 0.6999 0.6268 0.5781 0.4644 0.3245 0.2175

26 0.2540 0.2270 0.2271 0.2149 0.2103 0.1971 0.1906 0.1700 0.1578 0.1416 0.1132 0.1020
 25 0.4225 0.3760 0.3883 0.3593 0.3602 0.3322 0.3318 0.2890 0.2773 0.2546 0.1997 0.1641
 24 0.5668 0.5393 0.5808 0.5247 0.5455 0.4889 0.5025 0.4254 0.4221 0.3745 0.2943 0.2129
 23 0.6596 0.6576 0.7127 0.6493 0.6889 0.6091 0.6235 0.5318 0.5300 0.4607 0.3738 0.2540
 22 0.7150 0.7217 0.7820 0.7194 0.7659 0.6787 0.6930 0.5963 0.5943 0.5199 0.4308 0.2946
 21 0.7877 0.8293 0.8923 0.8356 0.8906 0.7918 0.7983 0.6963 0.6847 0.5962 0.5051 0.3283
 20 0.8427 0.9049 0.9682 0.9165 0.9743 0.8718 0.8753 0.7688 0.7506 0.6603 0.5660 0.3665
 19 0.8807 0.9435 1.0084 0.9569 1.0163 0.9130 0.9196 0.8089 0.7917 0.7018 0.6050 0.4028
 18 0.9628 1.0350 1.0915 1.0530 1.0966 1.0075 1.0010 0.8938 0.8578 0.7582 0.6452 0.4427
 17 1.0368 1.1344 1.1874 1.1603 1.1954 1.1135 1.0949 0.9881 0.9326 0.8224 0.6970 0.4718
 16 1.0801 1.1750 1.2377 1.2076 1.2440 1.1629 1.1456 1.0358 0.9776 0.8653 0.7379 0.4971
 15 1.1007 1.1903 1.2573 1.2267 1.2660 1.1859 1.1741 1.0629 1.0083 0.8975 0.7727 0.5225
 14 1.1386 1.2606 1.3307 1.3057 1.3431 1.2682 1.2521 1.1409 1.0741 0.9627 0.8344 0.5436
 13 1.1549 1.2878 1.3595 1.3363 1.3737 1.3043 1.2911 1.1819 1.1133 1.0053 0.8785 0.5640
 12 1.1581 1.2858 1.3575 1.3328 1.3727 1.3075 1.3028 1.1966 1.1354 1.0321 0.9090 0.5823
 11 1.1725 1.3191 1.3911 1.3687 1.4066 1.3510 1.3484 1.2464 1.1808 1.0794 0.9504 0.5936
 10 1.1771 1.3256 1.4031 1.3777 1.4210 1.3689 1.3758 1.2728 1.2126 1.1063 0.9593 0.5958
 9 1.1742 1.3133 1.3962 1.3698 1.4232 1.3702 1.3897 1.2828 1.2345 1.1148 0.9364 0.5921
 8 1.1861 1.3349 1.4289 1.4019 1.4611 1.4129 1.4402 1.3292 1.2809 1.1574 0.9546 0.5956
 7 1.2025 1.3779 1.4917 1.4622 1.5243 1.4862 1.5199 1.3999 1.3409 1.2143 0.9774 0.5982
 6 1.2071 1.4067 1.5469 1.5126 1.5789 1.5498 1.5907 1.4535 1.3809 1.2495 0.9762 0.5909
 5 1.1888 1.3946 1.5611 1.5208 1.6014 1.5681 1.6177 1.4518 1.3711 1.2264 0.9269 0.5633
 4 1.1338 1.2996 1.4611 1.4277 1.5386 1.4748 1.5303 1.3389 1.2742 1.1019 0.7996 0.5028
 3 0.9945 1.0476 1.1302 1.1357 1.2527 1.1632 1.1973 1.0411 1.0111 0.8145 0.5925 0.4005
 2 0.6673 0.6241 0.6358 0.6616 0.6839 0.6652 0.6443 0.5900 0.5410 0.4387 0.3299 0.2317

26 0.1999 0.2178 0.1945 0.1985 0.1799 0.1764 0.1549 0.1410 0.1423 0.1192 0.0967
 25 0.3330 0.3654 0.3279 0.3518 0.3066 0.3146 0.2659 0.2464 0.2373 0.1967 0.1674
 24 0.4771 0.4960 0.4772 0.5163 0.4526 0.4727 0.3921 0.3698 0.3153 0.2569 0.2181
 23 0.5823 0.5857 0.5886 0.6222 0.5654 0.5792 0.4922 0.4728 0.3756 0.3038 0.2572
 22 0.6418 0.6441 0.6518 0.6821 0.6317 0.6402 0.5551 0.5399 0.4265 0.3461 0.2932
 21 0.7394 0.7291 0.7521 0.7682 0.7349 0.7287 0.6482 0.6343 0.4688 0.3772 0.3183
 20 0.8096 0.7933 0.8241 0.8296 0.8081 0.7906 0.7161 0.7003 0.5126 0.4111 0.3482
 19 0.8490 0.8351 0.8628 0.8652 0.8462 0.8240 0.7538 0.7380 0.5498 0.4445 0.3770
 18 0.9359 0.9175 0.9493 0.9421 0.9308 0.8955 0.8300 0.7890 0.6024 0.4878 0.4104
 17 1.0306 0.9982 1.0441 1.0205 1.0244 0.9714 0.9135 0.8534 0.6412 0.5178 0.4318
 16 1.0751 1.0393 1.0874 1.0593 1.0691 1.0088 0.9572 0.8950 0.6709 0.5429 0.4521
 15 1.0970 1.0633 1.1089 1.0805 1.0918 1.0293 0.9837 0.9238 0.6984 0.5677 0.4737

14 1.1674 1.1154 1.1808 1.1322 1.1656 1.0848 1.0540 0.9862 0.7205 0.5846 0.4847
 13 1.2003 1.1414 1.2136 1.1556 1.2006 1.1119 1.0925 1.0228 0.7402 0.6021 0.4982
 12 1.2078 1.1489 1.2196 1.1602 1.2088 1.1196 1.1091 1.0431 0.7585 0.6205 0.5135
 11 1.2470 1.1748 1.2591 1.1855 1.2524 1.1539 1.1553 1.0837 0.7729 0.6379 0.5221
 10 1.2607 1.1869 1.2743 1.1999 1.2737 1.1800 1.1803 1.1060 0.7830 0.6462 0.5229
 9 1.2559 1.1887 1.2720 1.2059 1.2794 1.2007 1.1909 1.1153 0.7906 0.6508 0.5191
 8 1.2825 1.2103 1.3030 1.2326 1.3211 1.2486 1.2351 1.1560 0.8058 0.6601 0.5167
 7 1.3277 1.2448 1.3553 1.2728 1.3868 1.3197 1.3000 1.2078 0.8186 0.6649 0.5079
 6 1.3565 1.2681 1.3936 1.3043 1.4399 1.3849 1.3474 1.2383 0.8205 0.6593 0.4918
 5 1.3405 1.2607 1.3881 1.3102 1.4484 1.4181 1.3404 1.2195 0.7984 0.6343 0.4626
 4 1.2414 1.1966 1.2920 1.2586 1.3564 1.3650 1.2274 1.1141 0.7371 0.5821 0.4128
 3 0.9918 1.0155 1.0284 1.0732 1.0725 1.1208 0.9456 0.8460 0.6250 0.4884 0.3425
 2 0.5841 0.6219 0.5984 0.6579 0.6125 0.6074 0.5318 0.4583 0.4138 0.3162 0.2228

26 0.1723 0.1653 0.1699 0.1597 0.1524 0.1391 0.1231 0.1229
 25 0.3026 0.2810 0.3032 0.2812 0.2705 0.2471 0.2179 0.2134
 24 0.4456 0.4061 0.4470 0.4251 0.4113 0.3757 0.3261 0.2844
 23 0.5422 0.5001 0.5387 0.5363 0.5146 0.4791 0.4174 0.3387
 22 0.6012 0.5565 0.5909 0.5992 0.5758 0.5421 0.4795 0.3850
 21 0.6870 0.6419 0.6598 0.6883 0.6572 0.6264 0.5630 0.4190
 20 0.7536 0.7051 0.7125 0.7507 0.7165 0.6862 0.6236 0.4508
 19 0.7970 0.7427 0.7458 0.7864 0.7534 0.7209 0.6580 0.4806
 18 0.8679 0.8187 0.8096 0.8412 0.8100 0.7707 0.6978 0.5215
 17 0.9468 0.9004 0.8737 0.9058 0.8725 0.8291 0.7490 0.5492
 16 0.9931 0.9431 0.9087 0.9440 0.9102 0.8658 0.7853 0.5722
 15 1.0230 0.9685 0.9307 0.9684 0.9359 0.8917 0.8126 0.5947
 14 1.0889 1.0325 0.9752 1.0233 0.9883 0.9447 0.8659 0.6076
 13 1.1267 1.0669 0.9986 1.0528 1.0184 0.9764 0.8992 0.6208
 12 1.1450 1.0810 1.0085 1.0671 1.0353 0.9953 0.9203 0.6347
 11 1.1859 1.1198 1.0336 1.1016 1.0705 1.0324 0.9552 0.6413
 10 1.2086 1.1354 1.0479 1.1236 1.0952 1.0588 0.9717 0.6451
 9 1.2161 1.1353 1.0553 1.1370 1.1136 1.0782 0.9746 0.6482
 8 1.2508 1.1622 1.0783 1.1724 1.1516 1.1209 1.0083 0.6564
 7 1.3009 1.2013 1.1076 1.2157 1.1957 1.1733 1.0487 0.6588
 6 1.3323 1.2215 1.1250 1.2425 1.2225 1.2088 1.0689 0.6514
 5 1.3143 1.1956 1.1160 1.2336 1.2127 1.2014 1.0446 0.6266
 4 1.2089 1.0912 1.0591 1.1581 1.1375 1.1091 0.9318 0.5744
 3 0.9437 0.8560 0.8940 0.9214 0.8943 0.8462 0.6889 0.4802
 2 0.5079 0.4948 0.5175 0.5045 0.4816 0.4529 0.3785 0.3156

26 0.1305 0.1299 0.1441 0.1335 0.1262 0.1127 0.1014
 25 0.2250 0.2281 0.2391 0.2343 0.2090 0.1908 0.1787
 24 0.3218 0.3346 0.3135 0.3118 0.2734 0.2510 0.2355
 23 0.3965 0.4208 0.3684 0.3666 0.3219 0.2971 0.2789
 22 0.4457 0.4779 0.4141 0.4099 0.3636 0.3374 0.3173
 21 0.5107 0.5529 0.4527 0.4420 0.3956 0.3707 0.3421
 20 0.5619 0.6107 0.4889 0.4716 0.4319 0.4066 0.3678
 19 0.5978 0.6472 0.5229 0.5011 0.4685 0.4369 0.3945
 18 0.6609 0.6895 0.5709 0.5425 0.5102 0.4738 0.4269
 17 0.7250 0.7422 0.6051 0.5698 0.5384 0.4988 0.4456
 16 0.7637 0.7802 0.6303 0.5914 0.5604 0.5196 0.4633
 15 0.7922 0.8088 0.6525 0.6118 0.5807 0.5397 0.4819
 14 0.8425 0.8582 0.6675 0.6209 0.5937 0.5521 0.4879
 13 0.8747 0.8891 0.6802 0.6304 0.6058 0.5644 0.4967
 12 0.8935 0.9075 0.6910 0.6409 0.6179 0.5772 0.5074
 11 0.9232 0.9351 0.6972 0.6437 0.6263 0.5843 0.5086
 10 0.9341 0.9434 0.6990 0.6447 0.6325 0.5897 0.5086
 9 0.9318 0.9332 0.6987 0.6457 0.6383 0.5949 0.5081
 8 0.9460 0.9474 0.7036 0.6483 0.6482 0.6029 0.5085
 7 0.9623 0.9640 0.7045 0.6421 0.6530 0.6046 0.5011
 6 0.9599 0.9614 0.6975 0.6284 0.6500 0.5978 0.4869
 5 0.9210 0.9203 0.6754 0.6055 0.6345 0.5771 0.4631

4 0.8149 0.8058 0.6323 0.5696 0.5971 0.5349 0.4210
 3 0.6247 0.6050 0.5484 0.5016 0.5102 0.4540 0.3567
 2 0.3578 0.3431 0.3664 0.3466 0.3243 0.2936 0.2393

26 0.1014 0.0972
 25 0.1685 0.1760
 24 0.2154 0.2322
 23 0.2498 0.2704
 22 0.2803 0.3012
 21 0.2985 0.3223
 20 0.3229 0.3430
 19 0.3499 0.3643
 18 0.3842 0.3945
 17 0.4076 0.4137
 16 0.4274 0.4293
 15 0.4461 0.4440
 14 0.4558 0.4485
 13 0.4660 0.4535
 12 0.4762 0.4582
 11 0.4790 0.4544
 10 0.4779 0.4475
 9 0.4740 0.4383
 8 0.4714 0.4302
 7 0.4643 0.4178
 6 0.4521 0.4026
 5 0.4280 0.3788
 4 0.3880 0.3473
 3 0.3266 0.3009
 2 0.2114 0.2068

EDIT: IPROPT[19] = 2

Bundle Average Fast Group Fluxes
 (NEM / Reference LP) * 1.0E-14

	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63
32-	2.4892	2.8381	2.8308	2.4580	2.4448	2.7763	2.6852	2.1577	1.9687	2.1198	2.1297	2.0630	1.9390	1.7395	1.2352	0.6523
30-	2.8737	2.8011	2.7648	2.6754	2.6812	2.7373	2.6857	2.4564	2.3054	2.2655	2.2357	2.1325	1.9674	1.6452	1.1877	0.5702
28-	2.8584	2.7743	2.8030	2.7451	2.7293	2.8076	2.7842	2.6298	2.4365	2.4455	2.3329	2.2554	1.9716	1.6041	1.0256	
26-	2.4461	2.6702	2.7436	2.3193	2.3244	2.6695	2.7073	2.4476	2.3401	2.4276	2.3826	2.2399	1.9940	1.5778	0.9252	
24-	2.4003	2.6540	2.7170	2.3199	2.3657	2.7371	2.7673	2.5256	2.3647	2.5106	2.3981	2.2864	1.9564	1.5268	0.8634	
22-	2.6995	2.6908	2.7808	2.6568	2.7327	2.7069	2.7106	2.6316	2.5422	2.4892	2.3869	2.1915	1.9061	1.4483	0.7898	
20-	2.6048	2.6224	2.7398	2.6828	2.7581	2.7094	2.6931	2.7265	2.5908	2.5406	2.3278	2.1347	1.7255	1.2346	0.6168	
18-	2.1056	2.3846	2.5571	2.4081	2.5031	2.6271	2.7236	2.6130	2.5464	2.4413	2.2393	1.9176	1.4877	0.8567		
16-	1.9327	2.2590	2.3779	2.3031	2.3367	2.5228	2.5776	2.5292	2.4524	2.3964	2.1043	1.7436	1.1398			
14-	2.0976	2.2383	2.4159	2.4035	2.4920	2.4629	2.5119	2.4313	2.3975	2.1893	1.9383	1.5123	0.8807			
12-	2.1123	2.2162	2.3191	2.3722	2.3918	2.3798	2.3176	2.2463	2.1166	1.9471	1.5929	1.1700	0.6144			
10-	2.0546	2.1224	2.2537	2.2443	2.2961	2.2032	2.1490	1.9439	1.7748	1.5288	1.1748	0.7245				
08-	1.9317	1.9612	1.9781	2.0155	1.9841	1.9339	1.7500	1.5161	1.1676	0.8965	0.6231					
06-	1.7359	1.6456	1.6174	1.6183	1.5794	1.4856	1.2638	0.8761								
04-	1.2323	1.1893	1.0370	0.9551	0.9090	0.8251	0.6370									
02-	0.6508	0.5717														

Bundle Average Thermal Group Fluxes
 (NEM / Reference LP) * 1.0E-13

	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63
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32- 4.4113 5.1702 5.2687 3.9558 3.9277 5.2254 5.1078 4.2357 3.4777 4.7695 4.1100 4.6230 3.8026 3.6996 2.6907 1.8533
 30- 5.3761 5.0053 5.7130 4.8303 5.4470 4.8863 5.4526 4.5717 5.0098 4.2925 4.8392 4.0842 4.3382 3.3574 2.7615 1.9045
 28- 5.3410 5.7183 5.1214 5.1902 5.1415 5.2216 5.1979 5.0140 4.5112 4.7555 4.3453 4.4339 3.8489 3.6969 2.7478
 26- 3.9113 4.8347 5.1885 3.6845 4.2303 4.8328 5.6147 4.2032 4.6138 4.4932 5.0999 4.2164 4.4149 3.4049 2.5730
 24- 3.8351 5.4906 5.1334 4.2233 3.8662 5.1683 5.1959 4.5046 4.0833 4.8481 4.4349 4.5186 3.8147 3.1530 2.3891
 22- 4.9477 4.8281 5.1836 4.8182 5.1541 4.7985 5.4627 4.7451 5.2731 4.5370 5.0939 4.1422 4.2094 3.2004 2.1917
 20- 4.9714 5.3392 5.1307 5.5610 5.1744 5.3162 4.7684 5.1278 4.6683 4.7587 4.3152 4.2978 3.4642 2.8246 1.9618
 18- 4.1540 4.4273 4.6655 4.1359 4.3675 4.7506 5.1207 4.6550 5.1414 4.4773 4.8417 3.7180 3.2703 2.5864
 16- 3.4357 4.8595 4.3853 4.5699 4.0317 5.3615 4.6743 5.2900 4.4412 4.6590 4.0178 3.5675 2.9768
 14- 4.7202 4.2613 4.7172 4.4625 4.8225 4.4795 4.5844 4.4683 4.6605 4.1161 4.1896 3.2213 2.4473
 12- 4.0903 4.8812 4.3358 5.0929 4.4263 5.0624 4.2755 4.8383 4.0349 4.1955 3.2732 2.6796 1.9920
 10- 4.6033 4.0724 4.4341 4.2209 4.5309 4.1561 4.3186 3.7750 3.7384 3.2503 2.6819 2.1251
 08- 3.7962 4.3465 3.8577 4.4510 3.8548 4.2414 3.4974 3.3247 3.0771 2.4750 1.9872
 06- 3.6965 3.3581 3.7145 3.4995 3.4206 3.2573 2.8832 2.5566
 04- 2.6866 2.7605 2.7676 2.6352 2.4454 2.2513 2.0556
 02- 1.7868 1.9052

EDIT: IPROPT[40] = 1

Bundle Peak kW/ft (MLHGR) Map
 (NEM / Reference LP)

	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63
32-	9.8174	11.245	11.270	10.079	9.8226	11.189	10.631	8.0407	10.560	7.0612	9.0966	7.5646	9.5082	9.0475	6.6952	2.9674
30-	11.434	11.649	8.5694	10.880	9.1960	11.274	8.8862	10.596	7.6431	9.4310	7.6407	9.8433	8.3508	8.4999	6.4769	2.6784
28-	11.436	8.5960	11.091	10.755	11.241	11.539	11.144	9.6776	10.357	9.4705	10.207	10.504	9.6620	7.1779	4.3375	
26-	9.8746	10.809	10.717	10.848	7.9903	10.756	8.4728	11.518	9.0324	10.458	8.6419	10.512	8.2017	7.8811	3.7940	
24-	9.7049	8.8952	11.132	8.0546	9.7739	10.914	10.898	10.815	11.510	10.406	10.844	10.541	9.8276	7.8347	3.5768	
22-	10.688	10.939	11.328	10.676	10.815	10.851	8.7957	11.067	8.5888	10.929	9.1471	10.798	8.9362	7.7556	3.5077	
20-	10.131	8.5616	10.899	8.4967	10.809	8.8674	11.151	11.366	11.522	11.654	11.216	10.840	9.2106	6.9419	2.9923	
18-	7.9518	10.240	9.6763	11.385	10.779	11.107	11.359	11.967	10.395	11.795	9.3893	9.9533	8.1131	3.9539		
16-	10.359	7.4650	10.092	9.0099	11.402	8.5604	11.418	9.6832	12.114	11.991	10.877	8.9414	4.9255			
14-	6.9935	9.3880	9.4125	10.421	10.237	10.708	11.163	11.674	11.957	11.324	9.6607	8.3028	4.0679			
12-	9.0654	7.5096	10.175	8.4934	10.788	9.1654	11.045	9.4462	10.927	9.8191	8.8056	6.4643	3.1191			
10-	7.5186	9.7805	10.497	10.538	10.599	10.867	10.795	10.106	9.0950	8.4378	6.4614	3.8380				
08-	9.4196	8.0847	9.6843	8.3311	10.023	9.2493	9.3496	8.2643	5.0725	4.1351	3.2111					
06-	8.8571	8.4594	7.2416	8.2533	8.0688	8.0530	7.1710	4.0699								
04-	6.6573	6.4534	4.3838	3.9447	4.0934	3.7612	3.1094									
02-	2.9708	2.6944														

EDIT: IPROPT[40] = 1

Bundle MFLPD Map
 (NEM / Reference LP)

	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63
32-	0.7575	0.8677	0.8696	0.7777	0.7579	0.8633	0.8203	0.6204	0.8148	0.5448	0.7019	0.5837	0.7337	0.6981	0.5166	0.2290
30-	0.8822	0.8988	0.6612	0.8395	0.7096	0.8699	0.6857	0.8176	0.5897	0.7277	0.5896	0.7595	0.6444	0.6559	0.4998	0.2067
28-	0.8824	0.6633	0.8558	0.8298	0.8674	0.8904	0.8598	0.7467	0.7992	0.7307	0.7876	0.8105	0.7455	0.5538	0.3347	
26-	0.7619	0.8340	0.8269	0.8370	0.6165	0.8299	0.6538	0.8888	0.6969	0.8070	0.6668	0.8111	0.6329	0.6081	0.2927	
24-	0.7488	0.6864	0.8589	0.6215	0.7542	0.8421	0.8409	0.8345	0.8881	0.8030	0.8367	0.8133	0.7583	0.6045	0.2760	
22-	0.8247	0.8440	0.8741	0.8238	0.8345	0.8373	0.6787	0.8539	0.6627	0.8433	0.7058	0.8332	0.6895	0.5984	0.2707	
20-	0.7817	0.6606	0.8410	0.6556	0.8340	0.6842	0.8604	0.8770	0.8890	0.8992	0.8654	0.8364	0.7107	0.5356	0.2309	
18-	0.6136	0.7901	0.7466	0.8784	0.8317	0.8571	0.8765	0.9233	0.8021	0.9101	0.7245	0.7680	0.6260	0.3051		
16-	0.7993	0.5760	0.7787	0.6952	0.8798	0.6605	0.8810	0.7472	0.9347	0.9253	0.8393	0.6899	0.3801			
14-	0.5396	0.7244	0.7263	0.8041	0.7899	0.8262	0.8613	0.9008	0.9226	0.8738	0.7454	0.6406	0.3139			

12- 0.6995 0.5794 0.7851 0.6554 0.8324 0.7072 0.8523 0.7289 0.8432 0.7577 0.6794 0.4988 0.2407
 10- 0.5801 0.7547 0.8100 0.8131 0.8178 0.8385 0.8330 0.7798 0.7018 0.6511 0.4986 0.2961
 08- 0.7268 0.6238 0.7472 0.6428 0.7734 0.7137 0.7214 0.6377 0.3914 0.3191 0.2478
 06- 0.6834 0.6527 0.5588 0.6368 0.6226 0.6214 0.5533 0.3140
 04- 0.5137 0.4979 0.3383 0.3044 0.3159 0.2902 0.2399
 02- 0.2292 0.2079

Bundle CPR Map
 (NEM / Reference LP)

33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63

32- 1.8286 1.5925 1.5747 1.9825 1.9824 1.6119 1.6176 2.0121 1.8638 2.0408 1.8864 2.2377 2.1394 2.4841 3.1569 4.4843
 30- 1.5493 1.4920 1.6948 1.5587 1.7996 1.5403 1.7573 1.6200 1.9154 1.7673 2.0491 1.9472 2.3382 2.4781 3.3131 4.5743
 28- 1.5522 1.6892 1.6024 1.6138 1.6185 1.6061 1.5813 1.6315 1.6381 1.7690 1.7892 1.9756 2.1122 2.7322 3.0261
 26- 1.9916 1.5550 1.6113 1.8791 2.0882 1.5488 1.7160 1.5712 1.8583 1.6813 1.9856 1.8896 2.3014 2.6860 3.2627
 24- 2.0157 1.8009 1.6171 2.0833 1.9697 1.6219 1.5709 1.6381 1.6434 1.7543 1.7677 1.9541 2.1471 2.8583 3.5207
 22- 1.6730 1.5568 1.6126 1.5524 1.6202 1.5586 1.7605 1.5756 1.8579 1.7063 2.0020 1.9509 2.4059 2.9047 3.7768
 20- 1.6599 1.7902 1.5995 1.7229 1.5747 1.7731 1.5853 1.6586 1.6584 1.8072 1.8528 2.1054 2.4192 3.2690 4.2793
 18- 2.0473 1.6752 1.7200 1.6024 1.6727 1.5738 1.6560 1.6696 1.9332 1.7793 2.1394 2.2241 2.8194 3.3253
 16- 1.9038 1.9821 1.6881 1.8820 1.6663 1.8470 1.6540 1.9368 1.7959 1.9096 2.0429 2.5601 2.8500
 14- 2.0645 1.7881 1.7880 1.6955 1.7594 1.7237 1.8465 1.7799 1.9047 1.9872 2.3610 2.8515 3.4786
 12- 1.8994 2.0606 1.7962 1.9901 1.7714 2.0024 1.8661 2.1288 2.0333 2.3532 2.5896 3.4188 4.3063
 10- 2.2408 1.9532 1.9738 1.8886 1.9477 1.9444 2.0899 2.1899 2.4780 2.8403 3.4177 3.8624
 08- 2.1410 2.3457 2.1074 2.2861 2.1280 2.3831 2.3958 2.7745 2.7587 3.4291 4.2518
 06- 2.4819 2.4741 2.7175 2.6204 2.7171 2.8586 3.2108 3.2985
 04- 3.1585 3.3075 3.0063 3.1971 3.3700 3.6462 4.1509
 02- 4.5392 4.5698

Bundle R-Factors

33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63

32- 1.0110 1.0028 1.0027 1.0030 1.0027 1.0035 1.0027 1.0149 1.0407 1.0145 1.0407 1.0143 1.0407 1.0029 1.0407 1.0151
 30- 1.0031 1.0407 1.0144 1.0407 1.0139 1.0407 1.0130 1.0407 1.0140 1.0407 1.0122 1.0407 1.0104 1.0407 1.0051 1.0152
 28- 1.0027 1.0140 1.0027 1.0032 1.0027 1.0030 1.0027 1.0029 1.0407 1.0028 1.0407 1.0028 1.0407 1.0080 1.0145
 26- 1.0028 1.0407 1.0031 1.0407 1.0143 1.0407 1.0141 1.0407 1.0137 1.0407 1.0128 1.0407 1.0097 1.0028 1.0156
 24- 1.0027 1.0144 1.0026 1.0141 1.0066 1.0035 1.0026 1.0031 1.0407 1.0030 1.0407 1.0028 1.0407 1.0027 1.0156
 22- 1.0028 1.0407 1.0028 1.0407 1.0031 1.0407 1.0132 1.0407 1.0138 1.0407 1.0114 1.0407 1.0080 1.0027 1.0148
 20- 1.0027 1.0131 1.0026 1.0138 1.0026 1.0124 1.0407 1.0030 1.0407 1.0027 1.0407 1.0032 1.0407 1.0049 1.0152
 18- 1.0148 1.0407 1.0027 1.0407 1.0027 1.0407 1.0028 1.0407 1.0106 1.0407 1.0107 1.0407 1.0026 1.0157
 16- 1.0407 1.0140 1.0407 1.0136 1.0407 1.0143 1.0407 1.0118 1.0407 1.0028 1.0407 1.0028 1.0155
 14- 1.0143 1.0407 1.0029 1.0407 1.0028 1.0407 1.0027 1.0407 1.0028 1.0407 1.0057 1.0027 1.0154
 12- 1.0407 1.0128 1.0407 1.0128 1.0407 1.0111 1.0407 1.0105 1.0407 1.0055 1.0407 1.0095 1.0154
 10- 1.0140 1.0407 1.0027 1.0407 1.0028 1.0407 1.0031 1.0407 1.0034 1.0027 1.0096 1.0129
 08- 1.0407 1.0108 1.0407 1.0097 1.0407 1.0077 1.0407 1.0026 1.0153 1.0151 1.0145
 06- 1.0032 1.0407 1.0080 1.0027 1.0032 1.0027 1.0050 1.0150
 04- 1.0407 1.0055 1.0146 1.0153 1.0141 1.0139 1.0153
 02- 1.0142 1.0151

EDIT: IPROPT[45] = 1

Bundle FLCPR Map
 (NEM / Reference LP)

33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63

32- 0.7601 0.8729 0.8827 0.7011 0.7012 0.8623 0.8593 0.6908 0.7458 0.6811 0.7369 0.6212 0.6497 0.5596 0.4403 0.3100
 30- 0.8972 0.9317 0.8202 0.8918 0.7724 0.9024 0.7910 0.8580 0.7257 0.7865 0.6784 0.7138 0.5945 0.5609 0.4196 0.3039

28- 0.8955 0.8229 0.8675 0.8613 0.8588 0.8655 0.8790 0.8520 0.8486 0.7858 0.7769 0.7036 0.6581 0.5087 0.4593
 26- 0.6979 0.8939 0.8627 0.7397 0.6656 0.8975 0.8100 0.8847 0.7480 0.8267 0.7000 0.7356 0.6040 0.5175 0.4260
 24- 0.6896 0.7719 0.8596 0.6672 0.7057 0.8570 0.8848 0.8486 0.8458 0.7924 0.7863 0.7113 0.6474 0.4863 0.3948
 22- 0.8308 0.8929 0.8620 0.8954 0.8579 0.8918 0.7895 0.8822 0.7482 0.8146 0.6943 0.7125 0.5777 0.4785 0.3680
 20- 0.8374 0.7764 0.8690 0.8068 0.8827 0.7840 0.8768 0.8381 0.8382 0.7691 0.7502 0.6602 0.5746 0.4252 0.3248
 18- 0.6789 0.8297 0.8081 0.8674 0.8310 0.8832 0.8394 0.8325 0.7190 0.7812 0.6497 0.6250 0.4930 0.4180
 16- 0.7301 0.7013 0.8234 0.7386 0.8342 0.7526 0.8404 0.7177 0.7740 0.7279 0.6804 0.5429 0.4877
 14- 0.6733 0.7774 0.7774 0.8198 0.7900 0.8064 0.7528 0.7809 0.7298 0.6995 0.5887 0.4875 0.3996
 12- 0.7318 0.6746 0.7739 0.6985 0.7847 0.6942 0.7449 0.6529 0.6836 0.5907 0.5368 0.4066 0.3228
 10- 0.6203 0.7116 0.7042 0.7360 0.7137 0.7149 0.6651 0.6347 0.5609 0.4894 0.4067 0.3599
 08- 0.6492 0.5926 0.6596 0.6080 0.6532 0.5833 0.5802 0.5010 0.5039 0.4053 0.3269
 06- 0.5600 0.5618 0.5115 0.5305 0.5116 0.4863 0.4329 0.4214
 04- 0.4401 0.4203 0.4624 0.4348 0.4125 0.3812 0.3349
 02- 0.3062 0.3042

=====
 ===== Core Power and Margins Summary =====
 =====

CORE POWER AND FLOW:

Rated Thermal Power (MWt):	3833.000	Rated Coolant Flow Rate (Mlbm/hr):	112.500
Core Thermal Power (MWt):	3833.000	Core Coolant Flow Rate (Mlbm/hr):	93.752
Percentage Power:	100.000	Percentage Core Flow:	83.335
Core Average Exposure (GWD/STU):	13.7783	Number Fuel Assemblies:	800

HEAT DEPOSITION AND BYPASS

Average Linear Heat Rate (kW/ft):	5.2662	Bypass and WT Flow Fraction (%):	13.58
Average Heat Flux (MBtu/hr-ft ²):	0.1557	Total Bypass Flow Rate (Mlbm/hr):	12.733
Average Power Density (kW/l):	54.1418	Water Tube Flow Rate (Mlbm/hr):	0.000
Bypass Exit Void:	0.0000		

T/H CONDITIONS

Inlet Enthalpy (Btu/lbm)	532.6852	Inlet Subcooling (Btu/lbm):	21.5000
Inlet Temperature (F):	537.00	Avg. Coolant Void Fraction:	0.5332
Average Coolant Temperature (F):	550.88	Avg. Exit Void Fraction:	0.8001
Average Fuel Temperature (F):	959.00	Avg. Coolant Density (g/cc):	0.3744

PRESSURE DROP:

Core Inlet Pressure (psia):	1077.62	Core Support Plate DEL-P (psi):	1077.62
Core Exit Pressure (psia):	1058.28	Required Core Pres. Drop (psi):	19.34
Steam Dome Pressure (psia):	1047.00	Average Bundle Press. Drop (psi):	19.33

LIMITS:

Peak Core Rel. Power (TPF):	2.3003	Location:	(49-16, 6)
Peak Average Nodal Rel. Power:	1.7926	Location:	(51-16, 5)
Max. Ass. Axial Peaking (APF):	1.7733	Location:	(49-08, 4)
Max. Ass. Rel. Power (RPF):	1.3374	Location:	(33-28,)
Core MLHGR (CMRPD):	12.1139	Location:	(49-16, 6)
Core MFLPD (CMFLPD):	0.9347	Location:	(49-16, 6)
Core MAPLHGR (CLHGR):	9.0995	Location:	(51-16, 5)
Core MAPRAT (CMAPR):	0.8593	Location:	(49-16, 6)
Core MCPR:	1.4920	Location:	(35-30,)
Core MFLCPR (CMFCP):	0.9317	Location:	(35-30,)

 Eighth Core Power Imbalance: 5.949E-03

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