BNFL Fuel Solutions	**CALCULATION PACKAGE**	Calc. Pkg No. VSC-03.3605 File No.: VSC-03.3605 Revision: 0

PROJECT/CUSTOMER:

VSC-24 MSB Transportation Licensing Project

TITLE:

Palisades MSB Transportation Fuel Depletion Analysis

SCOPE:

Product:	☐	FuelSolutions™	☒	VSC-24	☐	Other _____	
Service:	☐	Storage	☒	Transportation	☐	Other _____	
Conditions:	☒	Normal	☐	Off-Normal	☒	Accident	☒ Other _All Conditions__

Component(s):

Prepared by:

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RECORD OF REVISIONS

REV.	AFFECTED PAGES	AFFECTED MEDIA	DESCRIPTION	NAMES (Print or Type)	
				PREPARER	CHECKER
0	All	24 CD-Rom discs	Initial Release	T. Lloyd	J. Hopf

RECORD OF VERIFICATION

	YES	NO	N/A
(a) The objective is clear and consistent with the analysis.	☒	☐	
(b) The inputs are correctly selected and incorporated into the design.	☒	☐	☐
(c) References are complete, accurate, and retrievable.	☒	☐	☐
(d) Basis for engineering judgments is adequately documented.	☒	☐	☐
(e) The assumptions necessary to perform the design activity are adequately described and reasonable.	☒	☐	☐
(f) Assumptions and references, which are preliminary, are noted as being preliminary.	☐	☐	☒
(g) Methods and units are clearly identified.	☒	☐	☐
(h) Any limits of applicability are identified.	☒	☐	☐
(i) Computer calculations are properly identified.	☒	☐	☐
(j) Computer codes used are under configuration control.	☒	☐	☐
(k) Computer codes used are applicable to the calculation.	☒	☐	☐
(l) Input parameters and boundary conditions are appropriate and correct.	☒	☐	
(m) An appropriate design method is used.	☒	☐	
(n) The output is reasonable compared to the inputs.	☒	☐	
(o) Conclusions are clear and consistent with analysis results.	☒	☐	

COMMENTS:

All comments resolved.

Verifier:

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1. INTRODUCTION

1.1 Objective

Determine the spent fuel isotopic composition for the eighteen VSC-24 MSBs currently loaded at the Palisades nuclear plant, making use of the known, as-loaded fuel data supplied by the customer (as described in Section 4.1). Include all nuclides to be used in the burnup credit criticality analyses to be performed for these MSBs. The output, or results, of this calculation are in the form of SAS2H computer output files that contain axial location-dependent isotopic concentrations for each fuel assembly contained in the MSBs. Concentrations are to be determined in terms of grams of a given nuclide per metric ton of initial uranium.

1.2 Purpose

The purpose of this calculation package is to provide the spent fuel isotopic compositions for the burnup-credit criticality analyses to be performed on the eighteen existing VSC-24 MSBs located at the Palisades nuclear plant.

1.3 Scope

This calculation applies to the eighteen VSC-24 casks currently loaded and situated on the Palisades ISFSI.

2. REQUIREMENTS

2.1 Design Inputs

None

2.2 Regulatory Commitments

None

3. REFERENCES

3.1 BFS Calculation Packages

3.1.1. VSC-03.3601, Rev 1, "SAS2H Isotopic Benchmark Analysis and Adjustment Factor Calculation." (Discussion of fuel temperature methodology and applicability; modeling specifics of SAS2H cases; fraction of ^{235}U concentration assumed for ^{234}U and ^{236}U concentrations.)

3.1.2. VSC-03.3602, Rev. 0, "MCNP Benchmark Evaluation and USL Function Calculation for Burned UO_2 Fuel Criticality Analyses." (Described selection and justification of Zircaloy-4 composition.)

3.1.3. CMPC.1701.001, Rev. 1, "Criticality Materials Property Calculations." (Used as source of 304-SS elemental composition.)

3.2 General References

3.2.1. Letter from S. Leblang to R. Quinn, "Palisades Fuel Data," November 29, 2004. (Source of fuel assembly type figures, fuel configuration details.)

3.2.2. Letter from S. Leblang to R. Quinn, "Additional Palisades Fuel Data," dfs-bfs-05-001, January 3, 2005. (Source of fuel configuration details, composition of fuel inserts, B_4C and Al_2O_3 densities and concentrations, presence or absence of guide tubes around B_4C rods, by assembly type.)

3.2.3. Letter from S. Leblang to R. Quinn, "Corrected Fuel Data," dfs-bfs-05-002, January 10, 2005. (Source of fuel configuration details, fuel dimensions, reactor cycle data, fuel insert information, information on fuel sub-types.)

3.2.4. Letter from S. Leblang to R. Quinn, "Clarification Fuel Data," dfs-bfs-05-004, February 28, 2005. (Source of fuel configuration details, guide bar effective radii, information on fuel sub-types.)

3.2.5. Letter from S. Leblang to R. Quinn, "Final Palisades Fuel Data Clarifications," dfs-bfs-05-006, June 13, 2005. (Source of fuel configuration details, information on fuel sub-types, correction to figure for assembly type H3, control blade compositions, information on control blade insertion; revised dimension for B_4C pellet radius and clad dimensions.)

3.2.6. *SAS2H: A Coupled One-Dimensional Depletion and Shielding Analysis Module*, NUREG/CR-0200, Revision 6, Volume 1, Section S2, ORNL/NUREG/CSD-2/V2/R6, Oak Ridge National Laboratory, September 1998. (General information on the SAS2H control module; source for description of treatment of boron concentrations over cycle.)

3.2.7. *(Reference not used.)*

3.2.8. *Topical Report on Actinide-Only Burnup Credit for PWR Spent Nuclear Fuel Packages*, DOE/RW-0472, Revision 2, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, September 1998. (Source of eighteen-region bounding axial power/burnup profiles; Figure 9—source of fuel temperature vs. rod axial thermal power.)

3.2.9. *MCNP5–A General Monte Carlo N-Particle Transport Code, Version 5*, RSICC Computer Code Collection CCC-660, Oak Ridge National Laboratory, April 2003. (General MCNP code reference.)

3.2.10. B00000000-01717-0210-00004, Rev. 0, *CRC Reactivity Calculations for McGuire Unit 1*, CRWMS (DOE Yucca Mtn. Project), June 1998. (NRC ADAMS Accession # MOL.19980728.0006 - Source for Zircaloy-4 material description, MCNP cross-sections. source for B_4C, Al_2O_3 material information.)

3.2.11. Handbook of Chemistry and Physics, 83rd Edition, page 4-39, CRC Press, 2002-2003. (Density for pure Al_2O_3)

3.2.12. Hermann, O.W., *et al*, *Validation of the SCALE System for PWR Spent Fuel Isotopic Composition Analyses*, ORNL/TM-12667, Oak Ridge National Laboratory, March 1995. (Presentation of general modeling assumptions and methodologies forming the basis of this calculation package. Source of fuel temperature and moderator correlations. Source of sample generic light elements and masses [methodology]. Source of expression for ^{234}U and ^{236}U concentrations as a function of ^{235}U concentration.)

3.2.13. Sanders, C.E., and Gauld, I.C., *Isotopic Analysis of High-Burnup PWR Spent Fuel Samples from the Takahama-3 Reactor,* NUREG/CR-ORNL/TM-2001/259, Oak Ridge National Laboratory, June 2002. (Presentation of general modeling assumptions and methodologies forming the basis of this calculation package.)

3.2.14. DeHart, M.D., and Hermann, O.W., *An Extension of the Validation of SCALE (SAS2H) Isotopic Predictions for PWR Spent Fuel,* ORNL/TM-13317, Oak Ridge National Laboratory, September 1996. (Presentation of general modeling assumptions and methodologies forming the basis of this calculation package.)

3.2.15. Rahimi, Meraj, *et al*, *Isotopic and Criticality Validation for PWR Actinide-Only Burnup Credit*, DOE/RW-0497, US DOE Office of Civilian Radioactive Waste Management, May 1997. (Presentation of general modeling assumptions and methodologies forming the basis of this calculation package.)

3.2.16. CAL-UDC-NU-000011, "Three Mile Island Unit 1 Radiochemical Assay Comparisons to SAS2H Calculations", US DOE Office of Civilian Radioactive Waste Management, April 2002. (Presentation of general modeling assumptions and methodologies forming the basis of this calculation package.)

3.2.17. User Manual for SASQUASH SAS2H Output Processor and MCNP Material Card Code, Version 1.02, SOFT.020.400, May 19, 2005. (Description of code inputs.)

3.2.18. Software Design and Implementation Report for SASIGEN Version 1.04, SOFT.019.200, Rev 2, March 17, 2005. (Description of SASIGEN code logic and functional requirements.)

3.2.19. Software Design and Implementation Report for SASQUASH Version 1.02, SOFT.020.100, Rev 2, May 25, 2005. (Description of SAQUASH code logic and functional requirements.)

3.2.20. User Manual for SASIGEN Automated SAS2H Input Preparation Code, Versions 1.03 and 1.04, SOFT.019.400, March 22, 2005. (Description of code inputs.)

3.2.21. NUREG/CR-0200, *Standard Composition Library*, Revision 6, Volume 3, Section M8, ORNL/NUREG/CSD-2/R6, Oak Ridge National Library, September 1998. (General SCALE 4.4 code reference and source of SS304 density.)

3.2.22. Letter from S. Leblang to R. Quinn, "Final Clarification Palisades Fuel Data," dfs-bfs-05-008, December 14, 2005. (Source of fuel configuration details and operating history for contributing rods from assemblies not loaded in the eighteen MSBs being analyzed.)

4. ASSUMPTIONS

4.1 Design Configuration

Although the work described in this calculation all pertains to loaded VSC-24 MSBs, there are no specific attributes of that design configuration that need be considered in this present calculation, since the MSB configuration does not itself affect the spent fuel isotopic compositions. The configuration details for the fuel assemblies themselves are provided in the customer-provided input data (References 3.2.1 through 3.2.5). Various aspects of the fuel configuration are discussed subsequently in this calculation package.

There are eighteen VSC-24 casks currently loaded and situated on the Palisades ISFSI. These casks are numbered 1-19, excluding 14, which was never placed into service. The casks are numbered as shown in Table 4-1.

Table 4-1 MSB's Loaded at Palisades

MSB Number	VSC Number
1	1
2	2
3	3
4	4
5	10
6	6
7	7
8	8
9	5

MSB Number	VSC Number
10	9
11	11
12	12
13	13
15	15
16	16
17	17
18	18
19	19

To avoid confusion that might arise through the reference to both VSC and MSB numbers, only the MSB numbers are used in this calculation package. In some cases (as in the SASIGEN code input files) the reader may encounter the term "cask" used to refer to an MSB.

4.1.1 Data for Fuel Assembly and Insert Types

Fuel design data, in the form of configurations and dimensions was supplied in Reference 3.2.3. This data is presented in Table 4-2, in terms and units consistent with the inputs to the SASIGEN (and

SAS2H) computer code. For example, since SASIGEN and SAS2H accept inputs for fuel dimensions on an inner and outer diameter basis and in units of cm, Table 4-2 also expresses these values in these terms. Items to be modeled in the SAS2H path-B model are input in terms of radial dimensions, so these are presented in the table. Dimensions are provided for the 10 fuel assembly types, generally corresponding to 10 differently-lettered batches. In several cases, such as with regions I, J, and K, a particular lettered batch is broken into multiple fuel types; this practice will be clear in referring to the table. Several characteristics do not change from type to type, and these have been omitted from the table. These include an array dimension of 15x15, a single, central, instrument tube, and a guide tube material (where present) of Zircaloy 4. Where guide tubes are present, there are eight per assembly, and the associated guide tube dimensions are provided; in all other cases, no guide tubes are present. Although in many cases the assemblies include multiple pin enrichments, a given assembly is modeled as having a single average enrichment due to the limitations of the SAS2H control module. None of the rods exhibit an axially-varying enrichment.

Table 4-2 Fuel Design Data

Design Characteristic	Type 1	Type 2	Type 3	Type 4	Type 5
Type Designation	A	EF	E	F	G
Rod Pitch[1]	1.3970	1.3970	1.3970	1.3970	1.3970
Fuel Pellet OD	0.9119	0.9093	0.8903	0.8903	0.8903
Clad OD	1.0503	1.0605	1.0541	1.0541	1.0541
Clad ID	0.9284	0.9284	0.9093	0.9093	0.9093
Active Fuel Height	335.28	333.76	334.77	334.77	334.77
Guide Tube IR	-	-	-	-	0.4966
Guide Tube OR	-	-	-	-	0.5283
Instrument Tube IR	0.4642	0.4642	0.4572	0.4572	0.4572
Instrument Tube OR	0.5251	0.5302	0.5271	0.5271	0.5271

Design Characteristic	Type 6	Type 7	Type 8	Type 9	Type 10
Type Designation	H	I1,I2,I3	J1,K1	I4,J2,K2	L
Rod Pitch	1.3970	1.3970	1.3970	1.3970	1.3970
Fuel Pellet OD	0.8890	0.8890	0.8890	0.8890	0.8903
Clad OD	1.0592	1.0592	1.0592	1.0592	1.0592
Clad ID	0.9093	0.9093	0.9093	0.9093	0.9093
Active Fuel Height	334.77	334.77	334.77	334.77	334.77
Guide Tube IR	0.4966	0.4940	0.4966	-	-
Guide Tube OR	0.5296	0.5296	0.5296	-	-
Instrument Tube IR	0.4547	0.4547	0.4547	0.4547	0.4547
Instrument Tube OR	0.5271	0.5296	0.5296	0.5296	0.5296

Descriptions of fuel inserts were also obtained from Reference 3.2.3; six different types of inserts are described. Table 4-3 presents the design data associated with the six fuel assembly insert types. This table presents the designation, number, clad and active absorber material, and dimensions for each

[1] All linear dimensions in centimeters (cm).

insert type. The table also gives the axial span (within the assembly fuel zone) occupied by the active absorber material. Note that insert Type 1 (plugging) is not included in these fuel depletion analyses, as these do not extend into the active fuel zone.

Table 4-3 Fuel Insert Design Data

Design Characteristic	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
Type Designation	Plugging	Boron (GH)	Boron (I)	Hafnium	Boron (A)	Boron (E)
Number of Absorber Rods	8	8	8	8	4	8
Rod Cladding Material	304L SS	Zr-4	Zr-4	Zr-4	Zr-4	Zr-4
Pellet Radius (cm)	N/A	0.3404	0.3404	0.3505	0.4521	0.4451
Clad Inner Radius (cm)	N/A	0.3632	0.3632	0.3632	0.4642	0.4547
Clad Outer Radius (cm)	0.4839	0.4216	0.4242	0.4216	0.5251	0.5271
Radial gap thickness (cm)	N/A	0.0229	0.0229	0.0127	0.0121	0.0095
Active Absorber Material	N/A	B_4C (4.7 w/o)	B_4C (4.7 w/o)	Hf	B_4C (1.7 w/o)	B_4C (7.7 w/o)
Bottom End of Poison Material[2] (in)	130.7	5.7	5.7	3.2	6.0	0.0
Top End of Poison Material (in)	140.6	125.7	125.7	132.3	126.0	131.8

Inserts Type 2 through Type 4 are not part of the assembly structure, but are inserted into the eight assembly guide tubes during reactor operation. These inserts are described directly in the "Fuel Insert Design Data" table of Reference 3.2.3. The Type 2 insert is used in the G and H assembly types, whereas the Type 3 and Type 4 inserts are used in the I and I1h assembly types, respectively. Insert Type 5 and Type 6 are actually neutron absorber rods that are part of the Type A and Type E assembly structures, fixed into the assembly array in place of fuel rods at various locations (as discussed in

[2] Measured from the bottom of the active fuel region.

Reference 3.2.4). These rods do not lie inside guide tubes. The radial and axial insert rod dimensions shown in Table 4-3 are taken from Reference 3.2.4 for the Type A assembly. For the Type E assembly, the dimensions of the neutron absorber rods are assumed to be the same as those of a standard fuel rod (the only difference being that B_4C absorber material is present in place of fuel). All of the above inserts are present during the entire assembly irradiation period, except for the Type 4 (hafnium) inserts, which are only present during the last two cycles of (I1h) assembly irradiation.

Reactor cycle data was provided in Reference 3.2.3 and is presented in Table 4-4. This table is presented in terms of the cycle number for each identified plant operating cycle. In several cases, an historic cycle is broken into two sub-cycles. This is done to account for mid-cycle outages, or—in the case of cycle 2—a change in core rated thermal power. The table shows the start and end date of each cycle, the core rated thermal power in megawatts, the average boron concentration in parts per million, and the core inlet and core outlet temperature in degrees Fahrenheit.

Table 4-4 Reactor Cycle Data

Cycle I.D.	Cycle Start Date	Cycle End Date	Core Rated Power (MWt)	Avg. Boron Concentration (ppm)[3]	Core Inlet Temp (ºF)	Core Outlet Temp (ºF)
1A	12/31/71	08/12/73	2200	820	522	566
1B	09/30/74	12/20/75	2200	450	522	566
2A	05/09/76	11/07/77	2200	500	522	566
2B	11/07/77	01/06/78	2530	50	536	583
3	04/20/78	09/08/79	2530	400	536	583
4	05/27/80	08/29/81	2530	400	536	583
5	12/31/81	08/12/83	2530	430	536	583
6	07/31/84	11/30/85	2530	450	537	587
7A	03/03/86	05/19/86	2530	930	537	587
7B	04/03/87	08/08/88	2530	440	537	587
8	11/28/88	09/15/90	2530	420	539	589
9	03/15/91	02/06/92	2530	370	536	581
10	04/18/92	06/04/93	2530	420	536	581
11A	11/08/93	02/17/94	2530	880	536	581
11B	06/18/94	05/22/95	2530	406	536	581

All fuel assemblies loaded into the MSB's are 15x15 bundles with a central instrument tube, eight zircaloy guide bars replacing eight fuel rods in the lattice, and, potentially, eight guide tubes located symmetrically around the interior of the assembly. Control blades, when present, are cruciform and located outboard the assembly. Control blades are further discussed in Sections 4.1.1.5 and 6.7.2.

[3] SAS2H represents the boron concentration as decreasing linearly throughout a modeled cycle from 1.9 to 0.1 times the input average concentration. This is described in Reference 3.2.6.

4.1.1.1 Fuel Assembly Guide Bars

Due to their somewhat irregular geometry, the guide tubes are characterized by an effective radius as shown in Table 4-5, taken from Reference 3.2.4. The use of these effective radius values preserves the quantity of zircaloy material in an assembly.

Table 4-5 Guide Bar Effective Radii

Fuel Assembly Batch	Effective Radius, cm
Types 1 and 2 (A and EF[4])	0.5953
Types 3-10 (E – L)	0.5776

4.1.1.2 Description of Fuel Sub-Types and Inserts

All features other than the control blades are shown pictorially in Figure 1 through Figure 21 (Control blades are discussed in Section 4.1.1.5). These figures include not only all of the fuel types as described in Table 4-2, but also a range of sub-types. Although all fuel of a particular type has the same general dimensions shown in Table 4-2, these sub-types further distinguish between the various types of inserts used in a particular assembly. The array layouts shown in Figure 1 through Figure 21 are taken from Reference 3.2.1. The configurations shown in Figure 1 through Figure 21 are combined with the fuel assembly and insert data shown in Table 4-1 and Table 4-2 to produce a complete description of the 22 assembly configurations for which SAS2H models are constructed. These configurations are described in Table 4-6, and the sub-types are described at length in Section 6.3.

Gd_2O_3 absorber rods are identical to fuel rods, other than the presence of Gd_2O_3 absorber material in the UO_2 fuel. The concentration of Gd_2O_3 absorber included in the fuel material for each sub-type are presented in Table 4-6. The geometries and material compositions of B_4C/Al_2O_3 absorber rods are given in Table 4-3 and in Section 4.1.1.3, respectively.

4.1.1.3 Non-Fuel Material Descriptions

The fuel rod cladding, guide tubes, guide bars, and poison rod cladding are all made of Zircaloy-4, as shown in References 3.2.2 and 3.2.3. As shown in Reference 3.2.2, the absorber material in the B_4C poison rods consists of an Al_2O_3 inert material with three different B_4C poison material concentrations (1.7%, 4.7%, and 7.7%), as shown in Table 4-6. Pure Al_2O_3 is loaded in sections of the poison rod that lie within the assembly active fuel zone, but above or below the axial bounds of the poison material;

[4] EF is also referred to as D in some of the reference data.

this material is conservatively modeled as the poison material in each axial region. Finally, the "I1h" assemblies described in Table 4-6 contain poison rods with pure hafnium absorber material.

The elemental compositions of all the component materials above are listed in Table 4-7. The composition for Zircaloy-4 is taken from Reference 3.2.10. This is the Zircaloy-4 cladding material composition that was modeled in the (Reference 3.1.2) burned-fuel benchmark analyses that the applied MCNP code bias factors are based upon. Modeling this same cladding material composition provides consistency between and these licensing-basis fuel depletion and criticality analyses and the associated code bias calculations.

The overall B_4C concentration for the three types of B_4C/Al_2O_3 poison rod are also shown in Table 4-6 (and taken from Reference 3.2.2). B_4C and Al_2O_3 are shown as compounds in Table 4-7, and are not broken down into component elemental densities. This is because, unlike all the other model component materials, their elemental breakdown is not taken directly from any reference, but instead must be calculated. These elemental compositions for B_4C and Al_2O_3 are presented in Table 6-1 and discussed in Section 6.2.2. The overall B_4C/Al_2O_3 material densities shown in Table 4-7 are taken from Reference 3.2.2. The "I1h" assembly hafnium absorber rods contain pure hafnium absorber material, over the axial bounds specified in Table 4-6. The density of the hafnium material is taken from Reference 3.2.3.

Table 4-6 Contents of Palisades Fuel Assembly Sub-Types[1]
(sheet 1 of 3)

Type Designation	A1	D1[2]	E1	F1	G1	G2	G3	H1	H1S
Number of Fuel Rods	212	216	208	216	208	208	208	208	208[3]
Rod Pitch	1.3970	1.3970	1.3970	1.3970	1.3970	1.3970	1.3970	1.3970	1.3970
Fuel Pellet OD	0.9119	0.9093	0.8903	0.8903	0.8903	0.8903	0.8903	0.8890	0.8890
Clad OD	1.0503	1.0605	1.0541	1.0541	1.0541	1.0541	1.0541	1.0592	1.0592
Clad ID	0.9284	0.9284	0.9093	0.9093	0.9093	0.9093	0.9093	0.9093	0.9093
Active Fuel Height	335.28	333.76	334.77	334.77	334.77	334.77	334.77	334.77	334.77
No. of Guide Tubes	0	0	0	0	8	8	8	8	8
Guide Tube IR	-	-	-	-	0.4966	0.4966	0.4966	0.4966	0.4966
Guide Tube OR	-	-	-	-	0.5283	0.5283	0.5283	0.5296	0.5296
Instrument Tube IR	0.4642	0.4642	0.4572	0.4572	0.4572	0.4572	0.4572	0.4547	0.4547
Instrument Tube OR	0.5251	0.5302	0.5271	0.5271	0.5271	0.5271	0.5271	.5271	.5271
No. of Poison Rods[4]	4	0	8	0	0	8	6[5]	0	0
PR Absorber Material	B_4C	-	B_4C	-	-	B_4C	Gd_2O_3	-	-
PR B_4C or Gd_2O_3 Conc. (w/o)	1.7 %	-	7.7 %	-	-	4.7 %	1.0 %	-	-
Bot. of Absorber (in)	6.0	-	0	-	-	5.7	0	-	0
Top of Absorber (in)	126.0	-	131.8	-	-	125.7	-	-	131.8

[1] All data is taken from Reference 3.2.3, except for the B4C and Gd2O3 concentrations, which are taken from Reference 3.2.2, and the A1 assembly poison rod axial span data, which is taken from Reference 3.2.4. The E1 assembly poison rod absorber material is assumed to cover the entire active fuel height.

[2] Assembly type D is referred to as assembly type EF in some reference materials.

[3] Although the assembly contains 56 stainless steel rods and 152 actual fuel rods (as shown in Figure 9), the model is constructed based on a standard 208 rod assembly; this is an appropriate approach since the SAS2H model is based on a single MTU. Not modeling the steel is shown to be conservative, by the Section 6.2.5 calculations.

[4] B_4C absorber rods lie within the assembly guide tubes, if guide tubes are present; Gd_2O_3 absorber rods replace fuel rods and do not lie inside the guide tubes. The specific fuel types with guide tubes surrounding the B_4C inserts–and those without guide tubes–are identified specifically in Section 4.1.1.3.1 and Table 4-8.

[5] Although the actual assembly contains four Gd_2O_3 rods, six are conservatively modeled to preserve symmetry and to avoid a possible dilution effect of modeling only four. (See Figure 7.)

Table 4-6 Contents of Palisades Fuel Assembly Sub-Types
(sheet 2 of 3)

Type Designation	H2	H3	I1,I2	I1h	I3	J1,K1	I4,J2,K2	L1	L1S
Number of Fuel Rods	208	208	208	208	208	208	216	216	216[6]
Rod Pitch	1.3970	1.3970	1.3970	1.3970	1.3970	1.3970	1.3970	1.3970	1.3970
Fuel Pellet OD	0.8890	0.8890	0.8890	0.8890	0.8890	0.8890	0.8890	0.8903	0.8903
Clad OD	1.0592	1.0592	1.0592	1.0592	1.0592	1.0592	1.0592	1.0592	1.0592
Clad ID	0.9093	0.9093	0.9093	0.9093	0.9093	0.9093	0.9093	0.9093	0.9093
Active Fuel Height	334.77	334.77	334.77	334.77	334.77	334.77	334.77	334.77	334.77
No. of Guide Tubes	8	8	8	8	8	8	0	0	0
Guide Tube IR	0.4966	0.4966	0.4940	0.4940	0.4940	0.4966	-	-	-
Guide Tube OR	0.5296	0.5296	0.5296	0.5296	0.5296	0.5296	-	-	-
Instrument Tube IR	0.4547	0.4547	0.4547	0.4547	0.4547	0.4547	0.4547	0.4547	0.4547
Instrument Tube OR	.5271	.5271	0.5296	0.5296	0.5296	0.5296	0.5296	0.5296	0.5296
No. of Poison Rods	8	8	0	8	8	0	8	0	0
PR Absorber Material	B_4C	Gd_2O_3	-	Hf[7]	B_4C	-	Gd_2O_3	-	-
PR B_4C or Gd_2O_3 Conc. (w/o)	4.7 %	4.0 %	-	-	4.7 %	-	4.0 %[8]	-	-
Bot. of Absorber (in)	5.7	0	-	3.2	5.7	-	-	-	0
Top of Absorber (in)	125.7	131.8	-	131.8	125.7	-	-	-	131.8

[6] Although the assembly contains 14 stainless steel rods (and 202 actual fuel rods), the model is constructed based on a standard 216 rod assembly; this is an appropriate approach since the SAS2H model is based on a single MTU. Not modeling the steel is shown to be conservative, by the Section 6.2.5 calculations.

[7] The "I1h" assembly inserts contain pure hafnium absorber material at a density of 13.31 g/cc, as shown in Table 4-3. The hafnium inserts are only present for the last two cycles of I1h assembly irradiation (Reactor Cycles 9 and 10).

[8] No Gd2O3 concentration data is given in Reference 3.2.2 for the J-L assemblies. For these assemblies, the concentrations are taken from the Reference 3.2.1 figures. These correspond to Figure 15 through Figure 21.

Table 4-6 Contents of Palisades Fuel Assembly Sub-Types (sheet 3 of 3)

Type Designation	L2	L2S	L3	L3S
Number of Fuel Rods	216	216[9]	216	216
Rod Pitch	1.3970	1.3970	1.3970	1.3970
Fuel Pellet OD	0.8903	0.8903	0.8903	0.8903
Clad OD	1.0592	1.0592	1.0592	1.0592
Clad ID	0.9093	0.9093	0.9093	0.9093
Active Fuel Height	334.77	334.77	334.77	334.77
No. of Guide Tubes	0	0	0	0
Guide Tube IR	-	-	-	-
Guide Tube OR	-	-	-	-
Instrument Tube IR	0.4547	0.4547	0.4547	0.4547
Instrument Tube OR	0.5296	0.5296	0.5296	0.5296
No. of Poison Rods	8	8	8	8
PR Absorber Material	Gd_2O_3	Gd_2O_3	Gd_2O_3	Gd_2O_3
PR B_4C or Gd_2O_3 Conc. (w/o)	4.0 %[10]	4.0 %	6.0 %	6.0 %
Bot. of Absorber (in)	0	0	0	0
Top of Absorber (in)	131.8	131.8	131.8	131.8

[9] Although the assembly contains 14 stainless steel rods (and 202 actual fuel rods), the model is constructed based on a standard 216 rod assembly; this is an appropriate approach since the SAS2H model is based on a single MTU. Not modeling the steel is shown to be conservative, by the Section 6.2.5 calculations.

[10] No Gd2O3 concentration data is given in Reference 3.2.2 for the J-L assemblies. For these assemblies, the concentrations are taken from the Reference 3.2.1 figures. These correspond to Figure 15 through Figure 21.

Table 4-7 Elemental Compositions of Non-Fuel Component Materials

Element	Zirc-4[1]	SS-304[2]	B_4C Abs (1.7%)[3]	B_4C Abs (4.7%)[3]	B_4C Abs (7.7%)[3]	Pure Al_2O_3	Hafnium Absorber
C	-	-	-	-	-	-	-
O	0.12	-	-	-	-	-	-
Si	-	-	-	-	-	-	-
P	-	-	-	-	-	-	-
S	-	-	-	-	-	-	-
Cr	0.1	19.0	-	-	-	-	-
Mn	-	2.0	-	-	-	-	-
Fe	0.2	69.75	-	-	-	-	-
Ni	-	9.25	-	-	-	-	-
Zr	98.18	-	-	-	-	-	-
Mo	-	-	-	-	-	-	-
Sn	1.4	-	-	-	-	-	-
Hf	-	-	-	-	-	-	100.0
Pb	-	-	-	-	-	-	-
B_4C	-	-	1.7	4.7	7.7	-	-
Al_2O_3	-	-	98.3	95.3	92.3	100.0	-
	Total Density (g/cc)						
	6.56	8.027	4.0101	3.3634	3.3074	3.97[4]	13.31[5]

[1] This composition is taken from Reference 3.2.10.

[2] This composition is taken from Reference 3.1.3.

[3] The overall density and the B_4C weight percentages for the three types of B_4C absorber material are given in Reference 3.2.2. This reference also specifies Al_2O_3 and the inert "filler" material for these rods, but it does not give the density for pure Al_2O_3.

[4] Taken from Reference 3.2.11.

[5] Pure elemental hafnium at 13.31 g/cc. Taken from Reference 3.2.3.

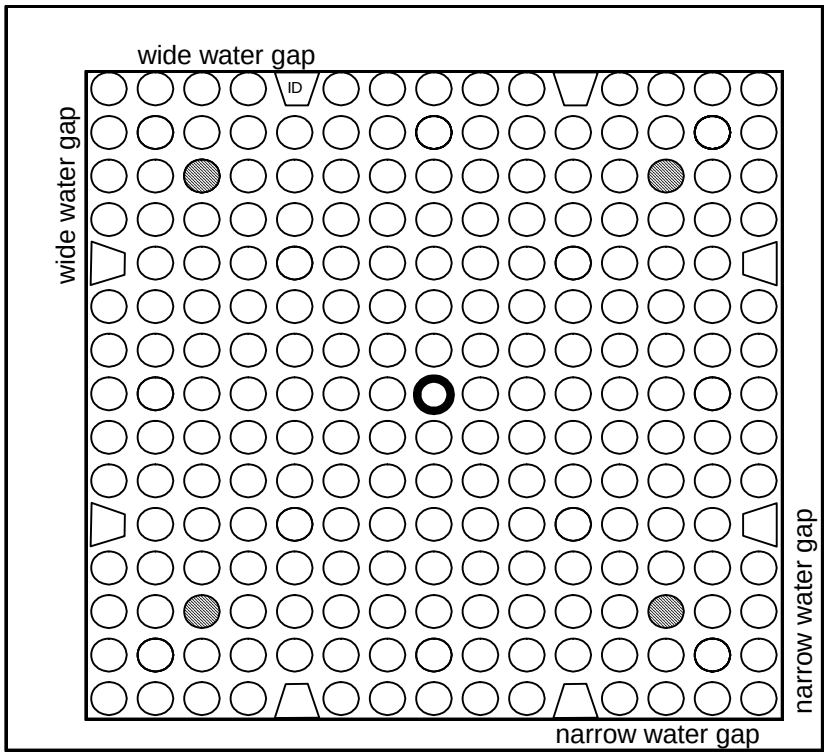
4.1.1.3.1 B_4C Rods – Presence and Absence of Guide Tubes

Several of the B_4C rods exist in assemblies with no guide tubes. In other cases, the B_4C rods are themselves loaded into guide tubes in the assembly. The types in each situation are taken from Reference 3.2.2. This reference clarifies the two different categories; these are described in Table 4-8.

Table 4-8 B_4C Insert Configurations

Description of B_4C Configuration	Assembly Types
No guide tubes; absorber rods are independent, fixed rods that take the place of assembly fuel rods.	A1 (Type 1), E1 (Type 3)
Guide tubes in assembly; absorber rods are inserted via poison clusters that are loaded from the top of the fuel assembly.	G2, H2, I3, and I1H (Types 5 through 8)

Figure 1 – Fuel Assembly Type A1



212 @ 1.65 w/o U235

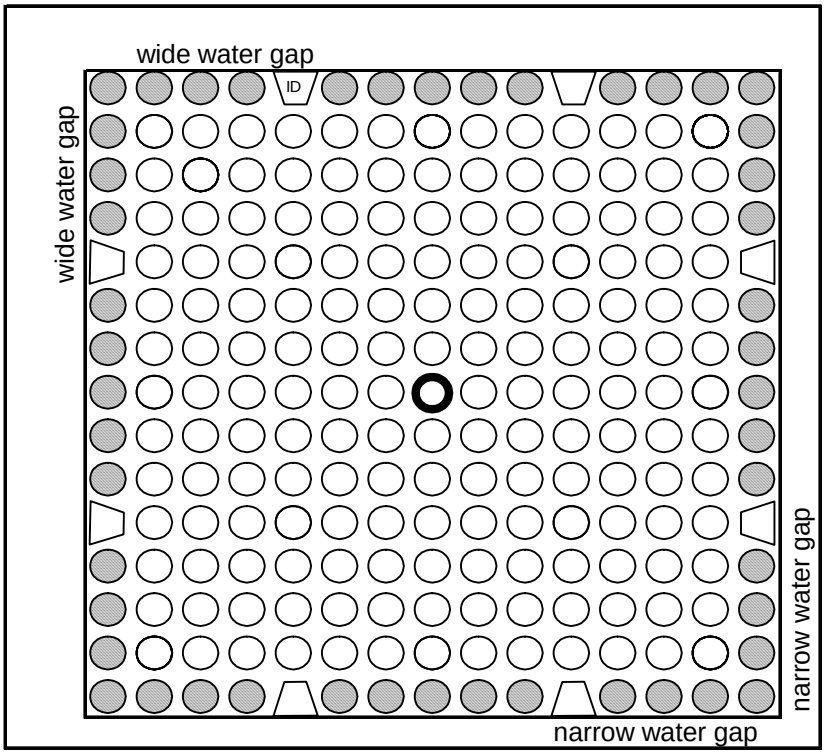
4 B_4C Rods - 1.7%

Instrument Tube

Guide Bar

Guide Bar with Orientation Mark

Figure 2 – Fuel Assembly Type D1 (also called “EF”)



48 @ 2.41 w/o U235

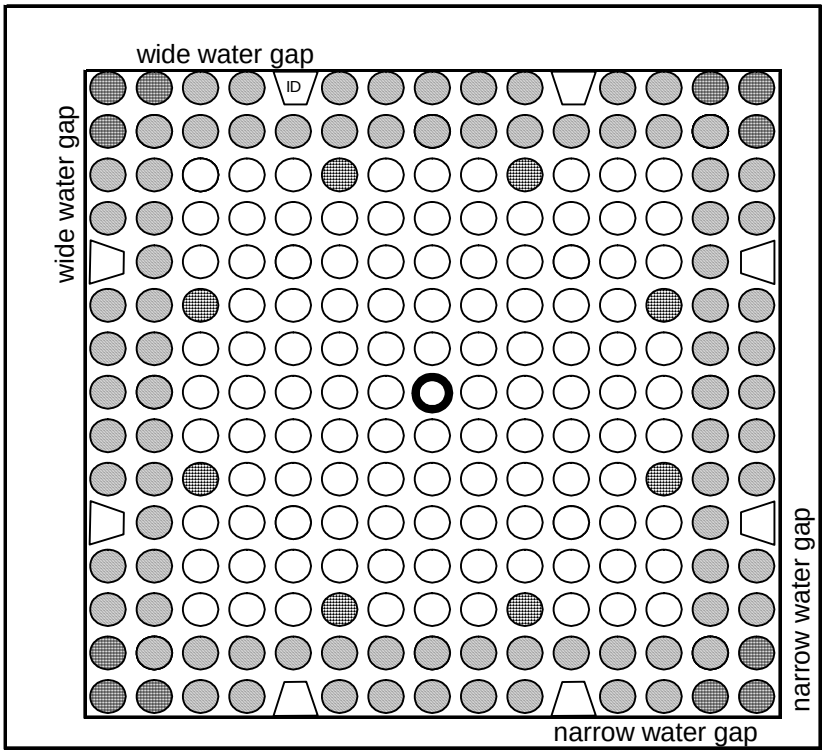
168 @ 2.83 w/o U235

Instrument Tube

Guide Bar

Guide Bar with Orientation Mark

Figure 3 – Fuel Assembly Type E1



12 @ 2.39 w/o U235

84 @ 2.81 w/o U235

112 @ 3.29 w/o U235

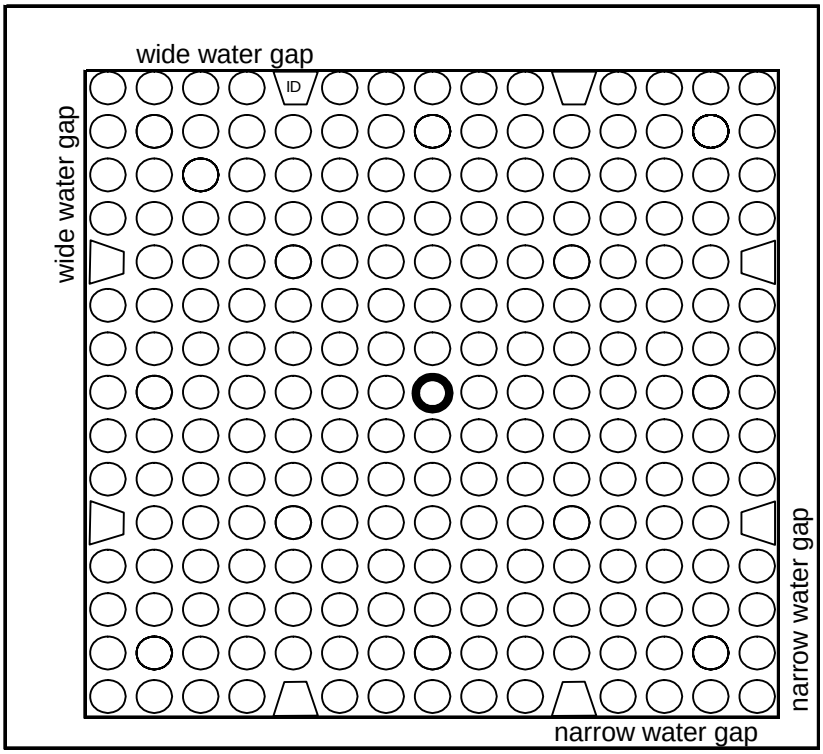
8 B_4C Rods - 7.7%

Instrument Tube

Guide Bar

Guide Bar with Orientation Mark

Figure 4 – Fuel Assembly Type F1



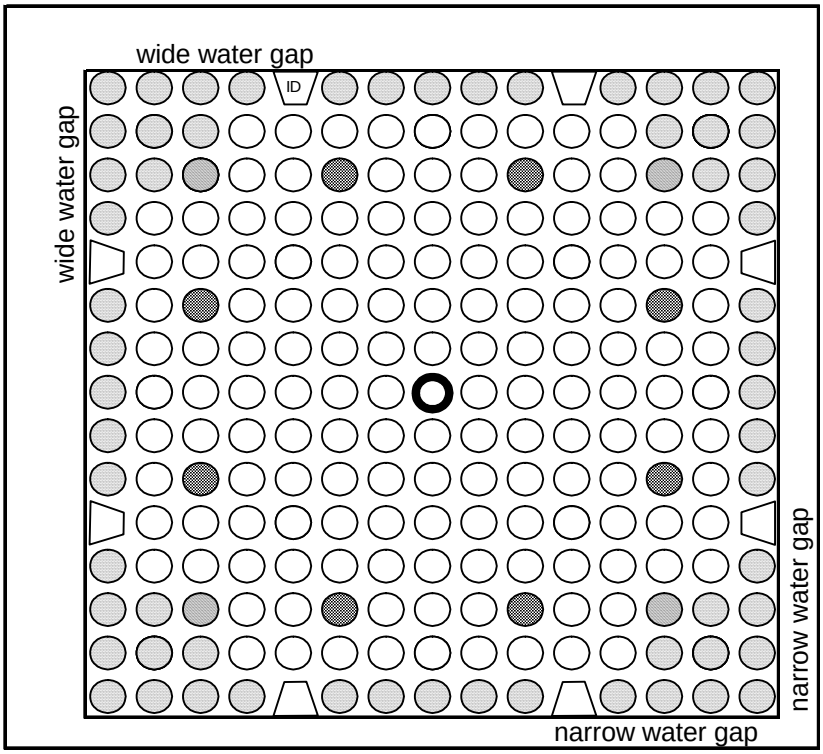
216 @ 1.50 w/o U235

Instrument Tube

Guide Bar

Guide Bar with Orientation Mark

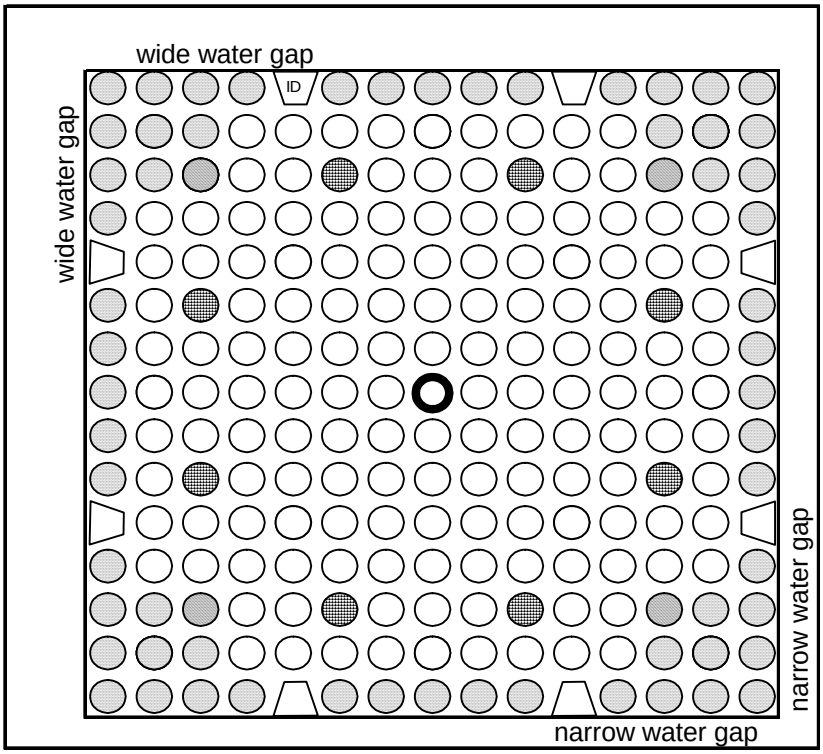
Figure 5 – Fuel Assembly Type G1



60 @ 2.52 w/o U235
4 @ 3.01 w/o U235
144 @ 3.20 w/o U235

8 Guide Tubes
Instrument Tube
Guide Bar
Guide Bar with Orientation Mark

Figure 6 – Fuel Assembly Type G2



60 @ 2.52 w/o U235

4 @ 3.01 w/o U235

144 @ 3.20 w/o U235

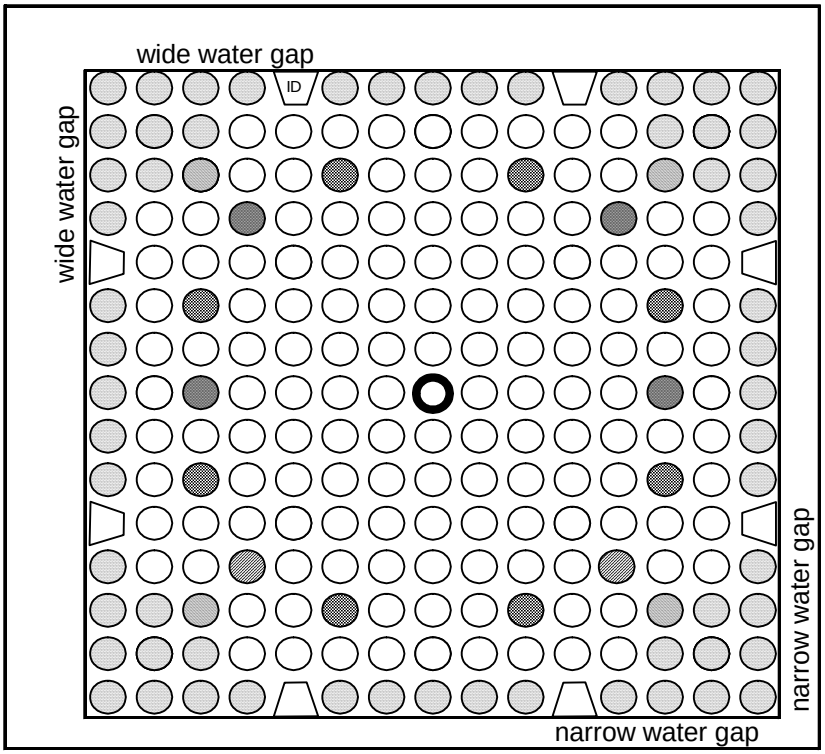
8 B_4C Rods - 4.7%

Instrument Tube

Guide Bar

Guide Bar with Orientation Mark

Figure 7 – Fuel Assembly Type G3



60	@	2.52	w/o U235
4	@	3.01	w/o U235
140	@	3.20	w/o U235
4	@	3.20	w/o U235 with 1% Gd_2O_3
2		extra	rods modeled as 1% Gd_2O_3

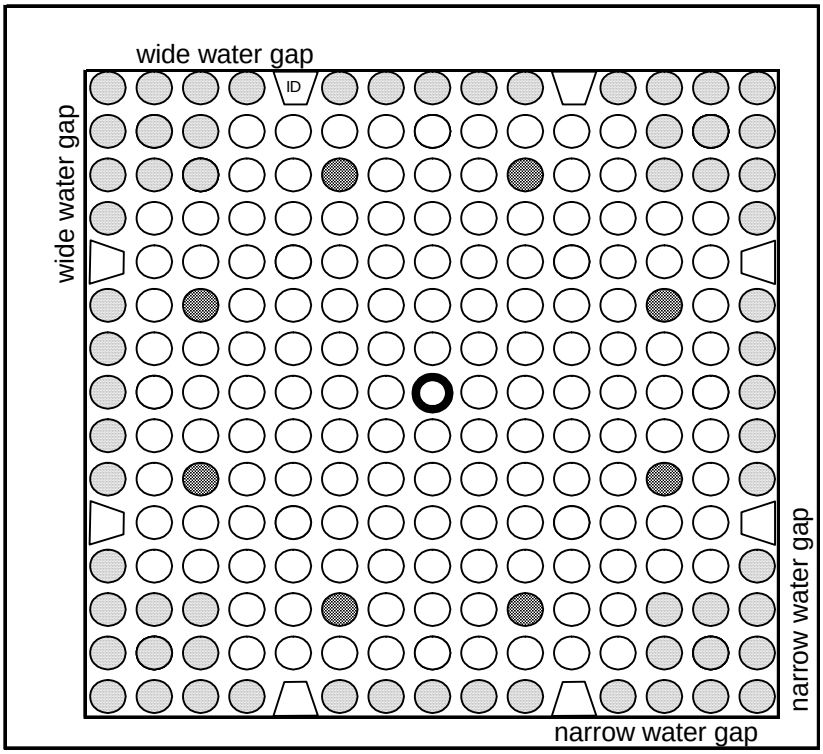
8 Guide Tubes

Instrument Tube

Guide Bar

Guide Bar with Orientation Mark

Figure 8 – Fuel Assembly Type H1



64 @ 2.90 w/o U235

144 @ 3.42 w/o U235

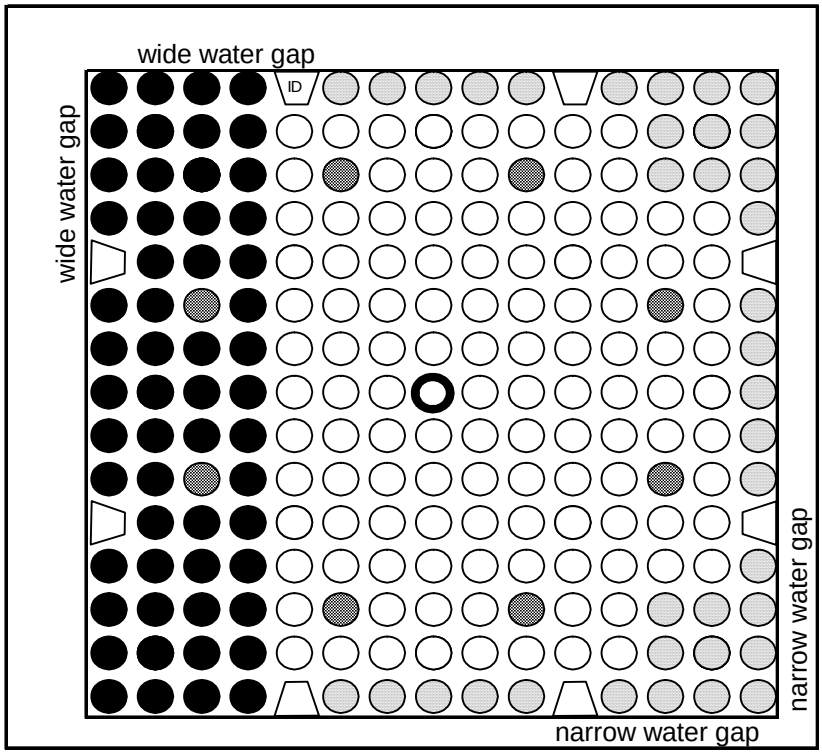
8 Guide Tubes

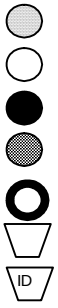
Instrument Tube

Guide Bar

Guide Bar with Orientation Mark

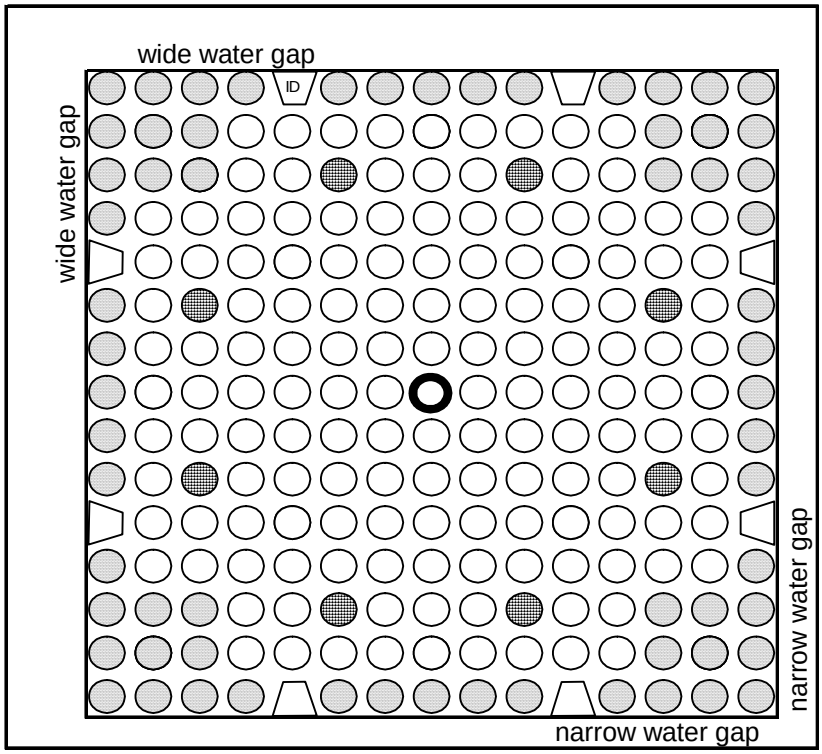
Figure 9 – Fuel Assembly Type H1S





37 @ 2.90 w/o U235
115 @ 3.42 w/o U235
56 Stainless Steel Rods
8 Guide Tubes
Instrument Tube
Guide Bar
Guide Bar with Orientation Mark

Figure 10 – Fuel Assembly Type H2



64 @ 2.90 w/o U235

144 @ 3.42 w/o U235

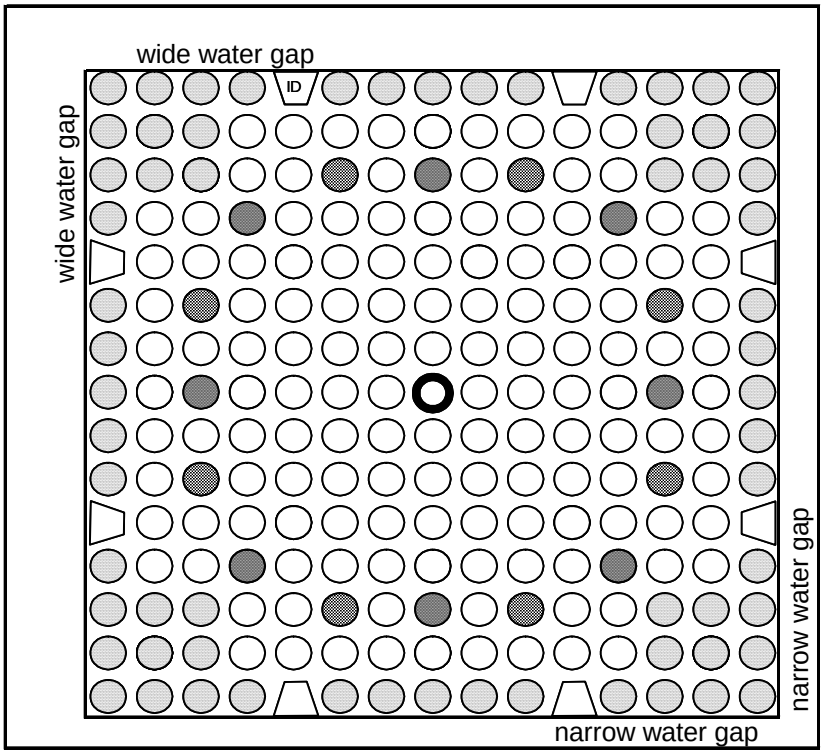
8 B_4C Rods - 4.7%

Instrument Tube

Guide Bar

Guide Bar with Orientation Mark

Figure 11 – Fuel Assembly Type H3



64 @ 2.90 w/o U235

136 @ 3.42 w/o U235

8 w/o 2.70 w/o U235 with 4% Gd_2O_3

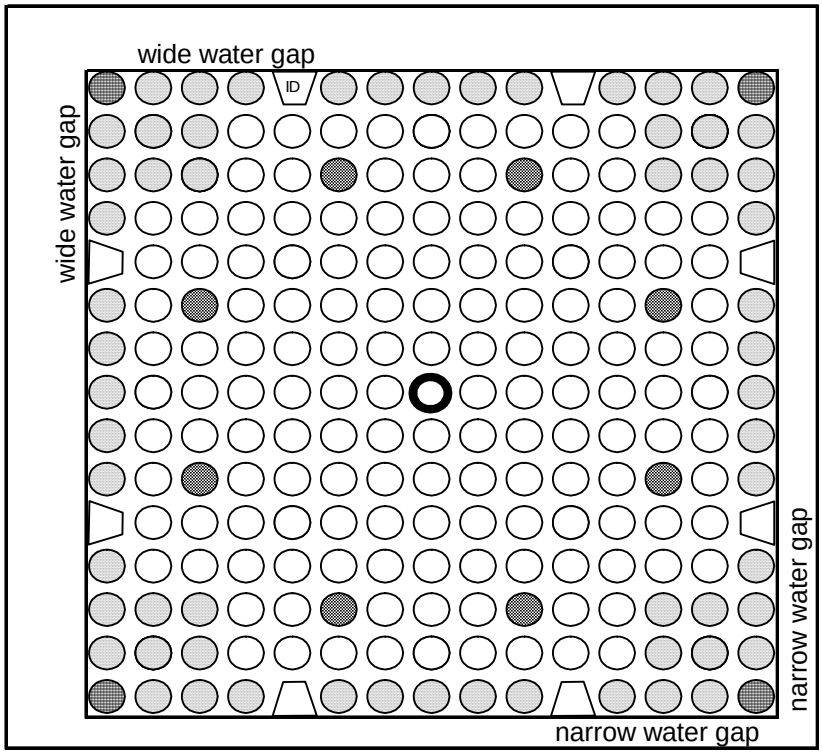
8 Guide Tubes

Instrument Tube

Guide Bar

Guide Bar with Orientation Mark

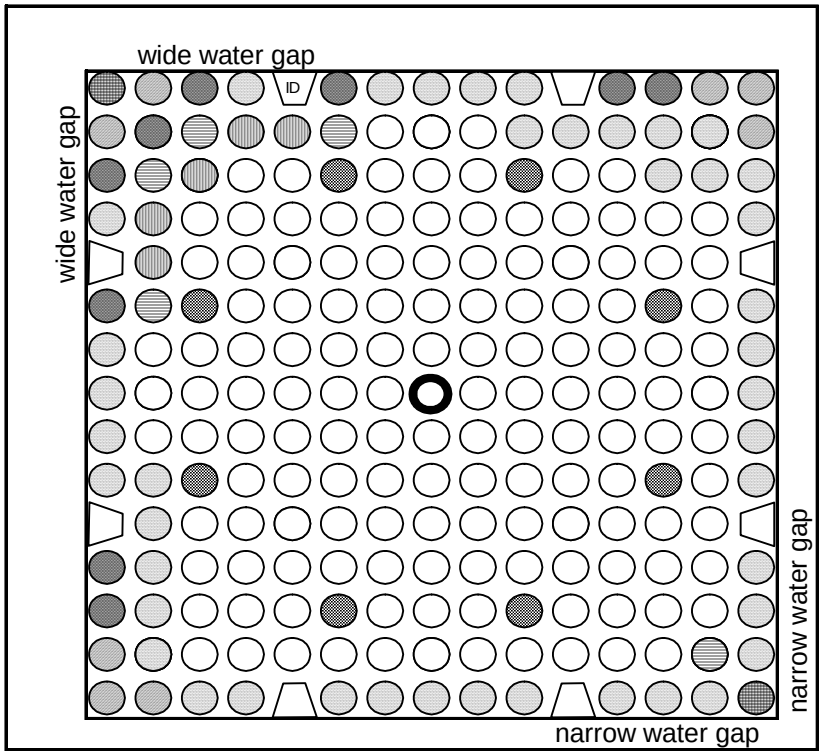
Figure 12 – Fuel Assembly Type I1 (J1, K1)



4	@	2.52	w/o U235
60	@	2.90	w/o U235
144	@	3.43	w/o U235

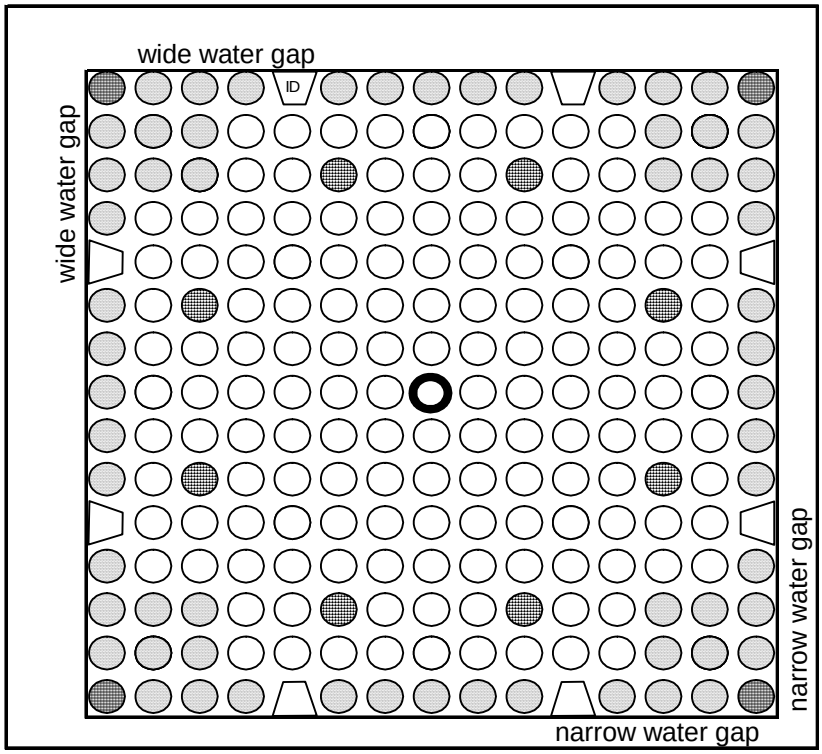
8	Guide Tubes
	Instrument Tube
	Guide Bar
	Guide Bar with Orientation Mark

Figure 13 – Fuel Assembly Type I2



2	@	1.87	w/o U235
8	@	2.40	w/o U235
9	@	2.81	w/o U235
40	@	2.90	w/o U235
5	@	3.01	w/o U235
5	@	3.28	w/o U235
139	@	3.43	w/o U235
8	Guide Tubes		
Instrument Tube			
Guide Bar			
Guide Bar with Orientation Mark			

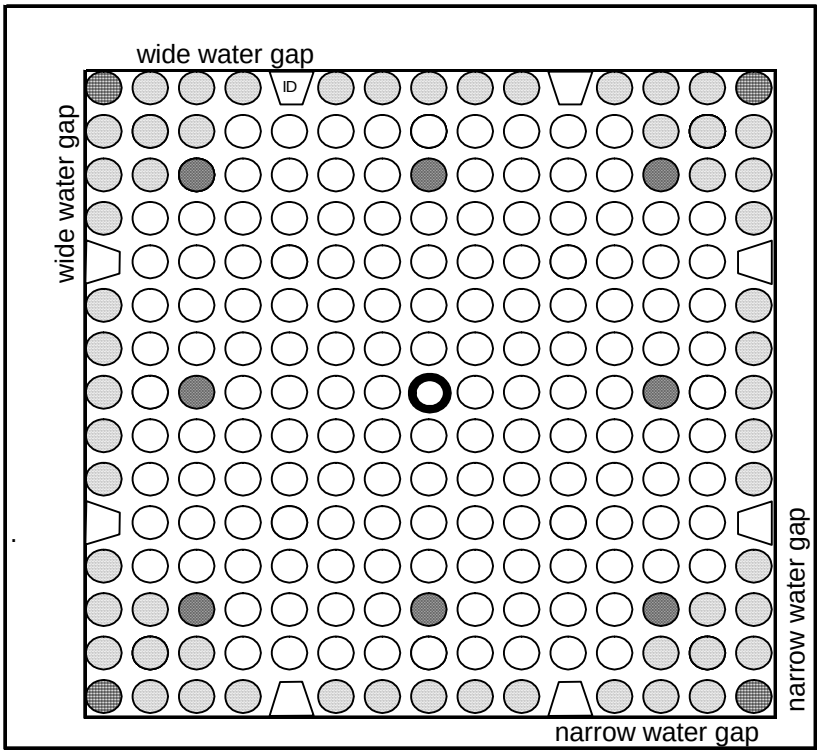
Figure 14 – Fuel Assembly Type I3



4 @ 2.52 w/o U235
60 @ 2.90 w/o U235
144 @ 3.43 w/o U235
8 B_4C Rods - 4.7%

Instrument Tube
Guide Bar
Guide Bar with Orientation Mark

Figure 15 – Fuel Assembly Type I4 (J2, K2)



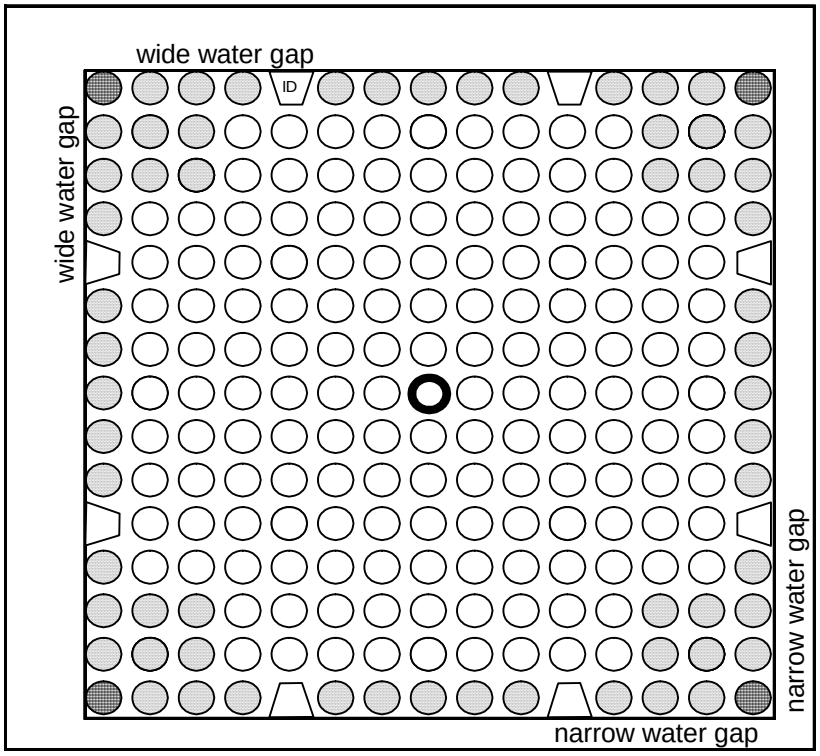
4 @	2.52	w/o U235
56 @	2.90	w/o U235
148 @	3.43	w/o U235
8 @	2.52	w/o U235 with 6% Gd_2O_3

Instrument Tube

Guide Bar

Guide Bar with Orientation Mark

Figure 16 – Fuel Assembly Type L1



4 @ 2.47 w/o U235
60 @ 2.85 w/o U235
152 @ 3.38 w/o U235

Instrument Tube
Guide Bar
Guide Bar with Orientation Mark

Figure 17 – Fuel Assembly Type L1S

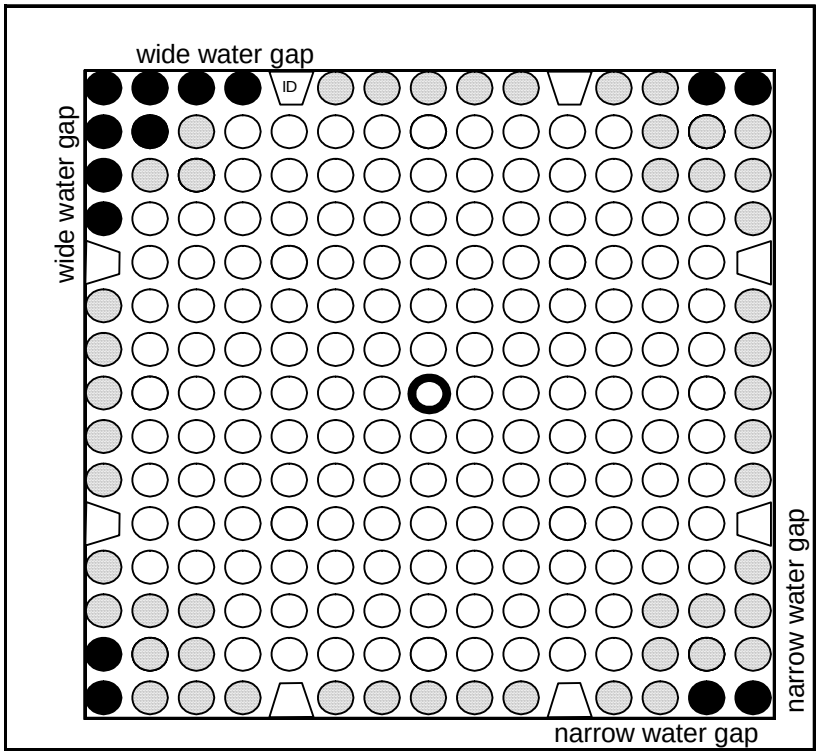
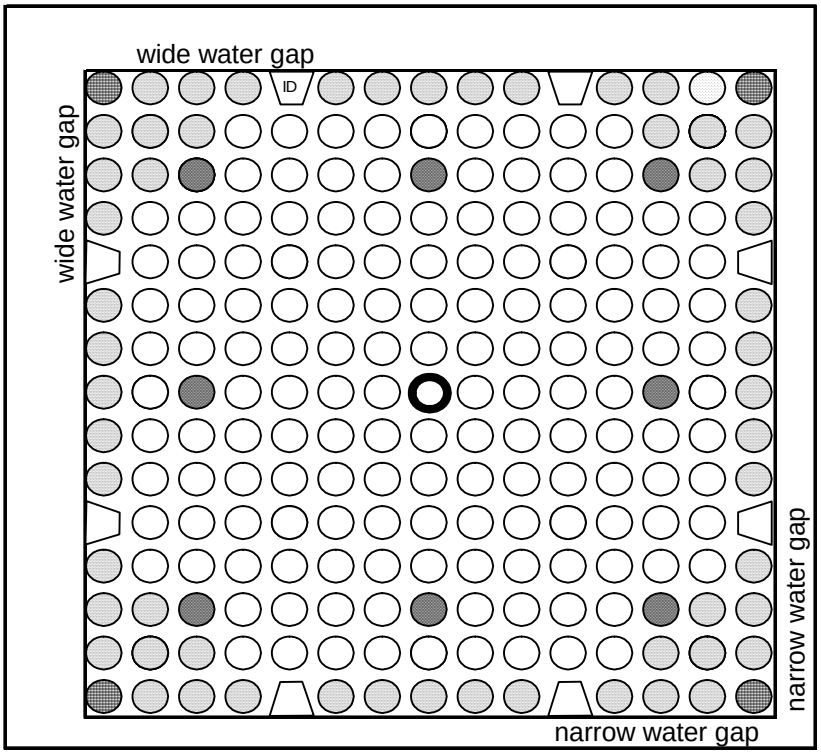


Figure 18 – Fuel Assembly Type L2



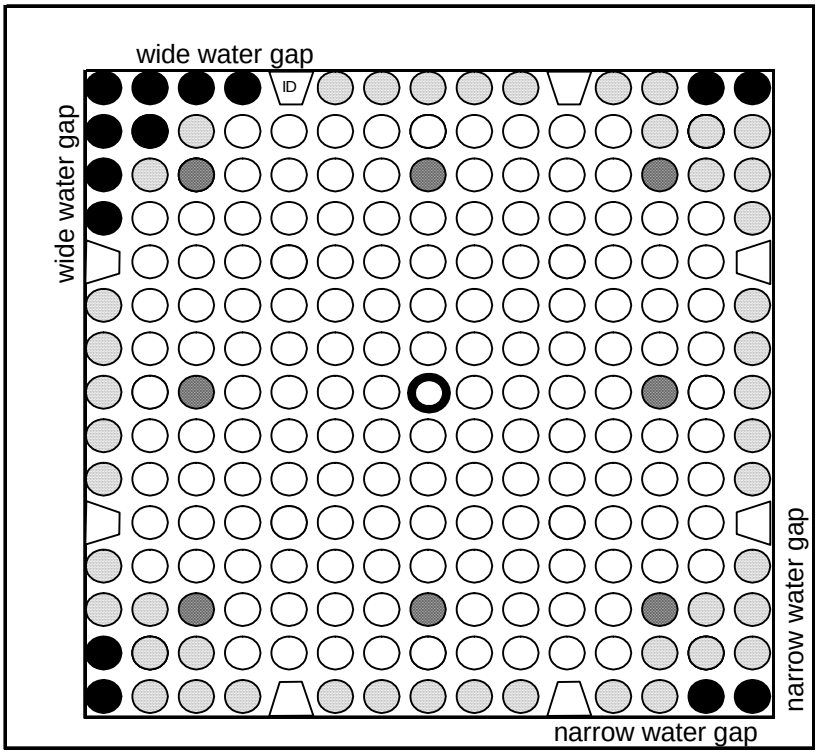
	4 @	2.47	w/o U235
	56 @	2.85	w/o U235
	148 @	3.38	w/o U235
	8 @	2.47	w/o U235 with 4% Gd_2O_3

Instrument Tube

Guide Bar

Guide Bar with Orientation Mark

Figure 19 – Fuel Assembly Type L2S



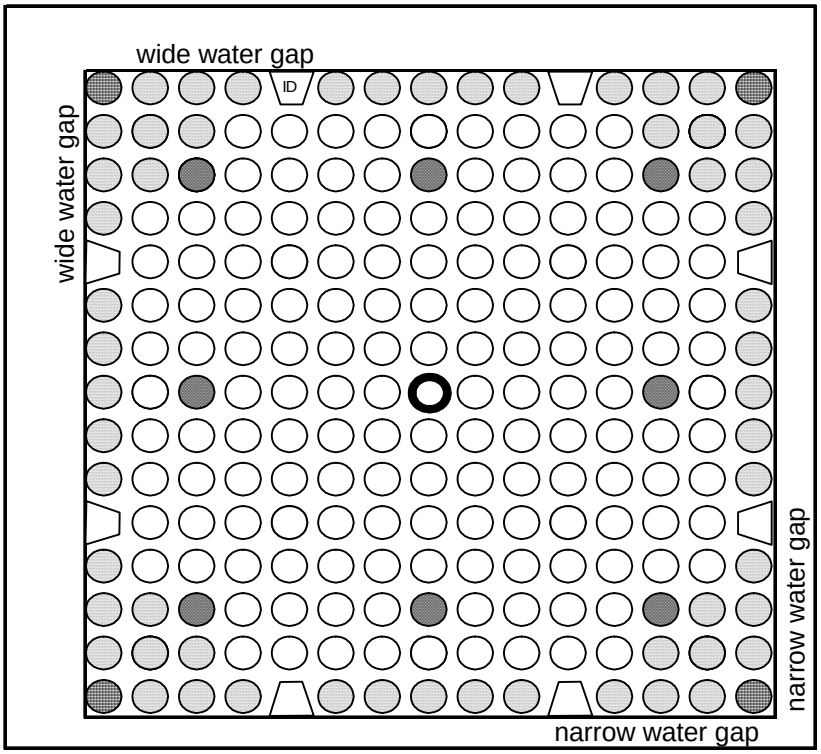
46	@	2.85	w/o U235
148	@	3.38	w/o U235
8	@	2.47	w/o U235 with 4% Gd_2O_3
14			Stainless Steel Rods

Instrument Tube

Guide Bar

Guide Bar with Orientation Mark

Figure 20 – Fuel Assembly Type L3



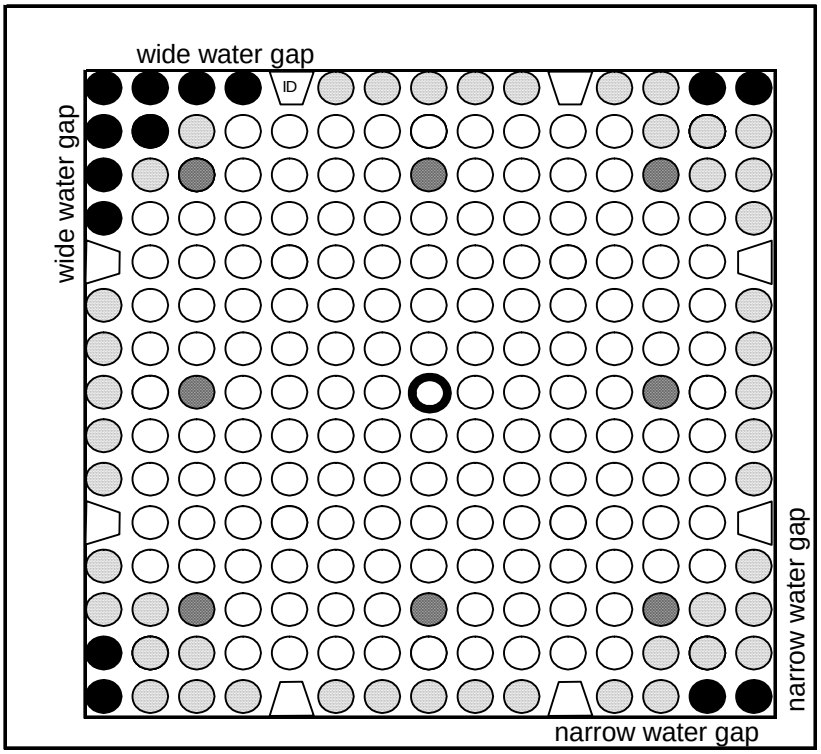
4 @	2.47	w/o U235
56 @	2.85	w/o U235
148 @	3.38	w/o U235
8 @	0.72	w/o U235 with 6% Gd_2O_3

Instrument Tube

Guide Bar

Guide Bar with Orientation Mark

Figure 21 – Fuel Assembly Type L3S



46 @ 2.85 w/o U235

148 @ 3.38 w/o U235

8 @ 0.72 w/o U235 with 6% Gd_2O_3

14 Stainless Steel Rods

Instrument Tube

Guide Bar

Guide Bar with Orientation Mark

4.1.1.4 Palisades Plant Notes on Specific Nomenclature and Fuel Types

In several assemblies, certain fuel rods are ultimately replaced with stainless steel dummy rods. The naming system for these assembly types is as follows:

1. H1 becomes H1S, following reconstitution.
2. L1 becomes L1S
3. L2 becomes L2S, etc.

The fuel type designations on the "Palisades Fuel Design Data Sheet" (References 3.2.1 and 3.2.3) are not used consistently, for example, in the fuel assembly detail figures. There are two key types for which multiple names are used.

1. The fuel referred to on the Data Sheet as type F is referred to in the figures as type XF. These are equivalent.

2. The fuel referred to on the Data Sheet as type EF is referred to in the figures as type D1. These are also equivalent.

4.1.1.5 Information on Control Blades

As stated in Reference 3.2.5, the Palisades control blades are composed of Silver/Indium/Cadmium in the following weight percentages—80% Ag, 15% In, and 5% Cd. The blades have a cruciform cross-section, 12.250 inches across. The Poison material is 0.176 inches wide, clad with 0.020" 304 SS, i.e., the total thickness is 0.216"[20]. The bottom 0.984" length is 304L SS, with the bottom 0.5" tapering to a 0.03" radius tip.

Based on References 3.2.2 and 3.2.5, these control blades are inserted to a significant degree only during Cycles 1A, 1B, and 2A, and then only those included in Group 4 are inserted—with the other groups remaining fully withdrawn. When partially inserted, these control blades range from 120" to 130" withdrawn. Table 4-9 presents the assemblies that were located adjacent to Group 4 control blades during Cycles 1A, 1B, and 2A; this information was taken from Reference 3.2.5.

[20] Reference 3.2.5 describes the poison material as being "0.176 inches wide, clad with 0.020" 304 SS (0.180" total). The parenthetical comment is assumed to be a typo, since the numbers are inconsistent. Furthermore, a clad thickness of 0.002", which would square with the math, is not a plausible mechanical design. The parenthetical comment appears to have been included simply to clarify that the clad thickness needed to be doubled to represent the material across the full blade thickness.

Table 4-9 Assemblies Adjacent to Group 4 Control Blades

Cycle	Assemblies Adjacent to Group 4 Control Blades
1A	A07, A11, A12, C05, A10, A15, A16, C06, A53, A54, A59, C15, A57, A58, A62, C16
1B	A07, A11, A12, C05, A10, A15, A16, C06, A53, A54, A59, C15, A57, A58, A62, B69
2A	EF0U, F08, F25, E61, EF0V, F56, F30, E11, EF1J, F51, F21, E43, EF1K, F11, F17, E50

4.1.2 Data for Individual Assemblies

In addition to the fuel assembly type and fuel insert type data presented above, data was also supplied in References 3.2.3 for each individual assembly loaded in the Palisades MSB's. Due to its voluminous nature, this data is presented in Attachment B. Two sets of data are presented to describe the assemblies. The first spreadsheet table, "Assembly Parameters – Palisades Plant," presents for each assembly seven categories of data. First, the MSB ID and slot location within that MSB are given for the assembly; both Attachment B tables are in fact listed in order of MSB and MSB location. Second, the Assembly ID is given in the next column. Assembly ID's are given in the form *Znn*, where Z is an alpha character (or, in several cases, two characters) describing the fuel assembly batch or region, and nn is a 2-digit numeric identifier uniquely describing a particular assembly. (Note that the MSB number and slot location of an assembly have no impact on the fuel depletion calculations themselves and are simply used as a form of tracking and identification.)

The third category of information in the Attachment B table is the Fuel Assembly Type. This is a numerical type, consistent with the Type Numbers presented in Table 4-2. The fourth and fifth categories of information are the assembly-average initial ^{235}U enrichment and the initial fuel mass, in metric tons of initial uranium. The sixth category of information in the table is the reactor cycle number associated with each assembly cycle. As an example, the assembly loaded into location 01 of MSB 1 (assembly G01) has been irradiated for three cycles; these cycles are Reactor Cycle 3, Reactor Cycle 4, and Reactor Cycle 5. The seventh and final type of information presented in the table is the fuel sub-type. These sub-types are presented in Figure 1 through Figure 21 and are described at length in Section 6.3.

The second table in Attachment B, "Burnup History by Specific Assembly – Palisades Plant," presents the initial and final burnup in each assembly-cycle for each assembly. These values are presented in units of GW-days per initial metric ton of uranium (GWD/MTU).

4.2 Design Criteria

No specific design criteria apply to this fuel depletion analysis.

4.3 Calculation Assumptions

1. The Palisades data does not include any information on fuel or clad temperature. As discussed in Section 5.3 and in Reference 3.1.1, the fuel temperature is calculated based on the fuel temperature vs. rod axial thermal power data shown in Figure 9 of Reference 3.2.8. After the fuel temperature is determined, the clad temperature is assumed to fall 25% of the way from the local moderator temperature and the local fuel temperature. This is accomplished through the specification of a *cladfrac* variable in the input to the SASIGEN code. Although the fuel and clad temperatures can be modeled with the distribution built into SASIGEN, there is no clear reference for the *cladfrac* value input to SASIGEN. This value, the ΔT of the clad as a ratio of the fuel ΔT is assumed to be 25%. This is considered to be conservative and is supported by the following observations.
    a. Since the clad-to-moderator ΔT is known to be a small but non-negligible component of the total fuel-to-moderator ΔT, it is reasonable to assume that the actual value will fall in a range of 10%-25%.
    b. The values in the SCALE validation reports (ORNL/TM-12667, etc.) imply a cladfrac value of ~16.5%, at least in the case of the Calvert Cliffs models.
    c. The clad is geometrically small (as a fraction of total fuel material) and is constructed of a material specifically selected for its small nuclear cross-sections. As a result, the selection of the *cladfrac* parameter over this range is unlikely to have a significant effect on the final spent fuel isotopic compositions.
2. All assembly cooling times are determined based on a single MSB shipment date. Based on discussions with the Owners Group, a date of 1/1/2015 has been agreed on as the earliest licensing date for shipping. This date has been assumed for all Palisades MSBs.
3. Palisades uses cruciform control blades. Based on References 3.2.2 and 3.2.5, these control blades are inserted to a significant degree only during cycles 1A, 2A, and 1B, and then only those included in Group 4 are inserted—with the other groups remaining fully withdrawn. When partially inserted, these control blades range from 120” to 130” withdrawn. Even when inserted, the control blades fall fully within the upper two axial zones, which represent the upper 1/9 (11.1%) of a given assembly. The SAS2H models conservatively model the control blade over the full length of the top two assembly zones.
4. When there are multiple enrichments in a single assembly, the approach is to average over the values. That is, all assembly enrichments are obtained from pin-weighted averages. The assembly average enrichment is also modeled for any Gd_2O_3 rods. This assumption must be made since the SAS2H code does not model individual fuel pins.
5. Each palisades assembly has eight guide bars. These are treated by placing an additional ring inside the outer ring of the SAS2H model. (The outer radius of this ring is referred to in the SASIGEN user manual as R_{extra}, and its material as M_{extra}.) This ring is filled with zircaloy (the material of the bars’ construction) and the thickness of this ring is chosen to preserve the total quantity of zircaloy. The model, along with a description and figure of the rings, is discussed in Section 6.2.1.

6. These analyses are based on the calculated (i.e., nominal) burnup values reported in Reference 3.2.3. A subsequent calculation will address uncertainties in the reported burnup value.
7. The stainless steel plugging rods that replace fuel rods in the latter cycles for certain assemblies are treated as fuel material. This assumption is discussed and validated in Section 6.2.5.
8. The Palisades G3 fuel assemblies include two features to be studied: 8 guide tubes; and 4 fuel rods doped with 1% Gd_2O_3. As an additional complexity, the Gd rods are positioned asymmetrically, with the 4 rods shifted upward as if 6 rods were effectively being positioned in the assembly (this is portrayed in Figure 7). These are modeled by modeling 15 features. Each feature is intended to represent the weighted combination of the following features: 8 guide tubes, 1 instrument tube (treated as a guide tube), and 6 Gd_2O_3 rods. This is discussed further in Section 6.2.4.
9. The Palisades data indicates one type of insert referred to as "Plugging" (Insert Type 1). As these are stainless steel and extend only a small distance below the top of the assembly (~1 inch), they are not modeled. The small effect these inserts would have had on a portion of the uppermost axial zone of the assemblies will have a still-smaller effect on the overall criticality of the system.
10. As the SCALE SAS2H module does not analyze individual rod effects, pin-by-pin variations in burnup and other parameters like temperature, etc., are not modeled. Assembly-average values are instead used for all input parameters, and all isotopic concentration results thus represent array-average values.
11. All parameters such as assembly thermal powers, component temperatures, water densities, etc., are calculated on a cycle-average basis. Variations in such parameters within a given reactor cycle are not modeled. This assumption is appropriate as it is consistent with the SAS2H modeling performed in the SAS2H benchmark evaluation (Reference 3.1.1); the models are thus consistent with the SAS2H code bias included in the criticality evaluation.
12. The analyses make use of the bounding 18-zone axial burnup profiles from Reference 3.2.8. It is assumed that the resulting axially-varying isotopic compositions are bounding (i.e., more reactive) for any given whole MSB. In the rare event of a single outlying assembly profile, it is recognized that the conservative treatment of the remaining twenty-three assemblies will more than account for the single outlier.
13. The initial (fresh fuel) concentrations of ^{234}U and ^{236}U are assumed to be 0.0089 and 0.0046% of the ^{235}U concentration, respectively. This is consistent with the approach taken in the Reference 3.1.1 SAS2H benchmark analyses.
14. For Gd_2O_3 rods, where it is necessary to enter fuel temperatures manually (as opposed to being calculated by the SASIGEN code), a representative temperature of 750 K is assumed.
15. For the determination of moderator densities for a given local moderator temperature, a reactor pressure of 2250 psi is assumed.
16. The axial moderator temperature profile is calculated based on a cosine power shape, as discussed in Section 5.3.5.
17. For cases where the Gd_2O_3 rod UO_2 density is not provided in 3.2.2, the density of the UO_2 in the Gd_2O_3 rods is assumed to equal that calculated for the standard, non Gd_2O_3 fuel rods of the given assembly.
18. The linear, SAS2H-default boron letdown function is assumed in all cases. During each reactor cycle, the soluble boron concentration in the reactor coolant decreases linearly from 1.9 times the cycle-average value (shown in Table 4-4) to 0.1 times the cycle-average value.

19. As discussed in Section 5.1.1, cross-section updates are performed every 5 GWd/MTU (or less) of exposure, consistent with the SAS2H benchmark (Reference 3.1.1) analysis. This library update frequency is assumed to be sufficient for these analyses.

5. CALCULATION METHODOLOGY

The fuel depletion calculations are performed using the SAS2H control module (Reference 3.2.6) of the SCALE 4.4 code package (Reference 3.2.12). All input files are constructed by means of the SASIGEN Code (Reference 3.2.18), although in several cases the SAS2H input files are subsequently edited. These subsequent editing operations are described in Section 6.7.

This section includes three main subsections. The first section discusses the general SAS2H methodology. The second section presents the general philosophies for path-B model treatments used in modeling the various types of fuel assemblies. Finally, the third section discusses the use of the SASIGEN code for the generation of the large number of SAS2H cases needed for modeling the contents of the 18 MSB's.

5.1 General SAS2H Methodology

The isotopic concentrations for each axial zone of each loaded assembly are calculated using the SAS2H module of the SCALE-4.4 code package (Reference 3.2.6), using the same methodologies and modeling assumptions that are used in the SAS2H analyses presented in the benchmark reference documents (References 3.2.12 through 3.2.16). Many of these modeling assumptions are discussed in Section 4. The calculations are performed using the 44GROUPNDF5 cross-section library. Various details of the SAS2H analysis methodology are discussed in the sub-sections below.

5.1.1 Cross-Section Updates

In the SAS2H input, the user defines one or more irradiation periods, or cycles. The average thermal power (in MW/MTU) for the period, along with the length of the period, and the lengths of any downtime (zero power) periods between the defined irradiation periods are listed in a single line of input that defines each cycle.

When SAS2H models fuel irradiation, it determines a neutron spectrum at the beginning of the cycle, which is calculated based upon the fuel composition present at the beginning of the cycle. SAS2H then applies a neutron flux, with the initial calculated spectrum, "irradiates" the fuel with that neutron flux, and determines the number of fissions and the creation of various isotopes. All of these calculations, during the irradiation period, are performed based on the initial neutron spectrum. Since the isotopic concentration itself affects the neutron spectrum, "irradiating" fuel for too long a period (or more specifically, for too much incremental burnup) leads to inaccuracy in the calculated isotopic concentrations, because the neutron spectrum is no longer valid for the latter parts of the irradiation period (as changes in the isotopic concentrations, and their effects on the neutron spectrum, are not accounted for).

For the above reason, SAS2H needs to periodically update its weighted cross-section set (and neutron energy spectrum) during the irradiation period, based on the changing fuel composition. SAS2H automatically updates the cross-section library at the end of each defined irradiation period, which is usually defined as one full reactor cycle. However, a full reactor cycle may be too long an irradiation period to yield accurate isotopic concentration results, without performing additional, mid-cycle cross-

section library updates. There is a SAS2H input command "nlib/cyc", which instructs the SAS2H code on how many cross-section updates it should perform within each defined cycle. If this value is set to 1, no mid-cycle updates are performed. If it is set to 2, a single update is performed halfway through the exposure period, etc… Note that the same number of mid-cycle updates are performed for each defined cycle, even if the length (or burnup increment) of the defined cycles varies widely. If one wishes to perform multiple cross-section updates in one cycle, but not in others, the only option is to break the cycle in question up into multiple defined irradiation periods. A down period must be defined between these irradiation periods, with a negligible duration.

As isotope concentrations primarily vary with burnup, as opposed to the length of irradiation, BFS decided to establish a maximum burnup increment criterion for cross-section update frequency, as opposed to irradiation period duration. Clearly, if the thermal power (or burnup rate) is very low, one can go for a longer period before a cross-section update is required. Conversely, if the thermal power (burnup rate) is extremely high, cross-section updates will be required sooner. After performing scoping evaluations, a maximum allowable burnup increment of ~5 GWd/MTU (to the nearest GWd) was selected. Scoping studies showed that calculated isotopic concentrations did not change significantly as the cross-section update frequency was increased beyond this point (i.e., were required for burnup increments smaller than ~5 GWd/MTU). Thus, in all of the SAS2H analyses performed in support of this benchmark evaluation, the cross-section libraries are always updated after burnup increments ~5 GWd/MTU or less. This is consistent with the approach taken in Reference 3.1.1.

5.1.2 "Tracked" Nuclides

As discussed above in Section 5.1, the isotope concentrations themselves can affect the neutronics of the system, which in turn affects the isotope concentration calculation. The neutron spectrum calculations model a finite set of nuclides within the spent fuel material. All other nuclides are simply built up (or destroyed) based on the resulting neutron flux and spectrum. The finite set of "tracked" nuclides basically includes all nuclides that measurably affect the neutron spectrum. All of the significant actinide (e.g., uranium and plutonium) nuclides are automatically "tracked" by the code. For fission products, if a given nuclide appears as part of the initial fuel material description, it is "tracked" (i.e., included in the neutron flux/spectrum calculations). Otherwise, it is not. While the "to-be-tracked" isotopes are included in the initial fuel material description card, their densities are set to 1.0×10^{-20} (to reflect the fact that their actual density is, in fact, zero at the start of fuel irradiation).

A set of 40 fission product isotopes are selected for "tracking" in these evaluations. In the (example) SAS2H inputs shown in all of the benchmark reports (References 3.2.12 through 3.2.16) a very similar set of fission product nuclides are listed in the fuel material card. The set of 40 isotopes selected by BFS includes all isotopes "tracked" by one or more of the SAS2H analyses presented in the benchmark reports. The set of isotopes selected for "tracking" in these evaluations are presented in Table 5-1.

Table 5-1 Isotopes "Tracked" by SAS2H Analyses[1]

^{94}Zr	^{94}Mo	^{95}Nb	^{95}Mo	^{99}Tc
^{103}Rh	^{105}Rh	^{106}Ru	^{126}Sn	^{131}Xe
^{134}Cs	^{135}Cs	^{137}Cs	^{143}Pr	^{143}Nd
^{144}Ce	^{144}Nd	^{145}Nd	^{146}Nd	^{147}Nd
^{148}Pm	^{147}Sm	^{148}Nd	^{148}Pm	^{148}Sm
^{149}Pm	^{149}Sm	^{150}Nd	^{150}Sm	^{151}Sm
^{151}Eu	^{152}Sm	^{153}Eu	^{154}Eu	^{154}Gd
^{155}Eu	^{155}Gd	^{157}Gd	^{158}Gd	^{160}Gd

5.1.3 Axial Burnup Profile Effects

These fuel depletion analyses explicitly treat the effects of axial variation in assembly burnup using the conservative (bounding) methods recommended in Reference 3.2.8. As is done in Reference 3.2.8, the assembly fuel zone is divided into 18 equal-height zones, each having its own (average) local burnup level. Reference 3.2.8 surveyed 3169 individual assembly burnup profiles, based on five different PWR assembly types and 105 different operating cycles. On the basis of this survey, three bounding (i.e., most reactive) axial burnup profiles, recommended for use in burnup-credit criticality evaluations, were determined. As discussed in Reference 3.2.8, modeling these very conservative profiles for all assemblies in a large canister (such as the 24-assembly MSB) will be bounding for any actual canister, despite the very rare possibility of a loaded assembly with a non-bounding (outlying) profile, due to the conservatism in the profiles modeled for all the remaining (23) assemblies in the canister.

The profiles vary with assembly-average burnup level, with three profiles defined for three burnup ranges (as described in Section 5.3.5). These three bounding profiles are presented in Table 5-2. The profile presented in Table 5-2 are normalized axial burnup profiles. The local burnup level for each axial zone is determined by multiplying the assembly-average burnup level by the factor shown for that axial assembly zone in Table 5-2.

For every individual assembly loaded into the 18 Palisades MSBs, the average burnup level is determined (from the individual assembly data given in Reference 3.2.3, and in Attachment B of this

[1] "Tracking" refers to placing the selected fission isotopes into the SAS2H initial UO_2 fuel description, at negligible density. SAS2H accounts for the effects of such isotopes when determining the spatially dependent neutron energy spectrum and flux, while performing its weighted cross-section calculations. SAS2H also performs cross-section updates for these isotopes. This is automatically done for all significant actinide isotopes. The selected fission product isotopes are the all the ones that have a significant effect on LWR assembly neutronics.

calculation), and the corresponding bounding axial burnup profile (from Table 5-2) is selected. For each loaded assembly, 18 individual SAS2H fuel depletion calculations are performed, one for each of the 18 axial assembly zones. After the cycle-average thermal power level of the entire assembly is determined (as discussed below in Section 5.1.5) it is multiplied by the axial profile factors shown (for each axial zone) in Table 5-2, to yield local thermal power levels for each of the 18 axial zones. These 18 thermal power levels are then applied in the 18 individual SAS2H analyses performed for each assembly.

Due to the very large number of analyses involved, (18 zones times 24 assemblies times 18 MSBs), BFS developed the SASIGEN code to automate the SAS2H input file creation process. The SASIGEN code's treatment of axial profile effects is discussed in Section 5.3.5.

Table 5-2 Bounding Axial Burnup Profiles[22]

Axial Zone[24]	Relative Burnup Level[23]		
	< 18 (GWd/MTU)	18-30 (GWd/MTU)	≥ 30 (GWd/MTU)
1	0.649	0.668	0.652
2	1.044	1.034	0.967
3	1.208	1.150	1.074
4	1.215	1.094	1.103
5	1.214	1.053	1.108
6	1.208	1.048	1.106
7	1.197	1.064	1.102
8	1.189	1.095	1.097
9	1.188	1.121	1.094
10	1.192	1.135	1.094
11	1.195	1.140	1.095
12	1.190	1.138	1.096
13	1.156	1.130	1.095
14	1.022	1.106	1.086
15	0.756	1.049	1.059
16	0.614	0.933	0.971
17	0.481	0.669	0.738
18	0.284	0.373	0.462

[22] These bounding (most reactive credible) axial burnup profiles are taken from Table 4-3 of Reference 3.2.8.

[23] Defined as the local burnup level (for the axial zone in question) relative to (or divided by) the assembly-average burnup level.

[24] The assembly fuel zone is divided into 18 equal-height axial zones, where Zone #1 lies at the bottom of the active fuel zone.

5.1.4 General Individual Assembly Parameter Determination

In addition to the assembly-type-specific physical parameters shown in Table 4-6, and the non-fuel material compositions shown in Table 4-7 (and in Section 6.1), various individual-assembly-specific parameters and calculated parameters must be entered into the SAS2H input files. Individual assembly parameters include the initial ^{235}U enrichment, the initial UO_2 fuel density, and the power history (i.e., the durations of the irradiation periods and the associated down period between and after the irradiation periods).

The initial enrichment and overall uranium mass for each individual assembly is given in Reference 3.2.3 and in the tables in Attachment B to this calculation. The Attachment B tables also lists the reactor cycles during which each individual assembly was present. The start and end dates of each cycle are given in Table 4-4. The initial enrichment values are used directly in the SAS2H input files, in the UO_2 fuel material description card. The initial UO_2 fuel density for each individual assembly is calculated based on its overall uranium mass, given in Attachment B, and the physical fuel pellet stack dimensions shown for its associated assembly type in Table 4-6.

SAS2H requires that an axial fuel length be entered. Instead of entering the actual assembly fuel zone length given (for each assembly type) in Table 4-2, an artificial fuel length which results in a model mass basis of exactly one MTU (of initial uranium) is calculated and entered. This is done so that the isotopic concentrations output by SAS2H, which are in units of grams per model basis, correspond to isotopic densities in units of grams per initial MTU of uranium. This expresses the SAS2H output in a more useful form for the subsequent criticality analyses. Based on the initial UO_2 fuel density discussed above (which is calculated based upon the actual assembly fuel length), the number of fuel rods (from Table 4-6), and the fuel pellet radius (also from Table 4-6), the length required to yield an overall assembly uranium mass is determined. As most Palisades assemblies have an overall uranium mass on the order of 0.4 MTU, this calculated, artificial fuel length is generally ~2.5 times the actual assembly fuel length.

The start and end dates of each Palisades reactor cycle are given in Table 4-4, and the table in Attachment B of this calculation (which was taken from Reference 3.2.3) specifies which reactor cycle corresponds to each irradiation cycle for each individual assembly. Based on this data, the irradiation period lengths and down period lengths can be determined for each individual loaded assembly. This includes the final down period length, or "cooling time" for the assembly. These period lengths are entered into each corresponding SAS2H input file. This final cooling time parameter is determined based on an assumed MSB shipping date of January 1, 2015, as discussed in Section 4.3.

As discussed in Section 5.3, the calculations discussed above are performed automatically using the SASIGEN code for each individual loaded assembly, using the individual-assembly data given in Attachment B, and the general data presented in Table 4-4 and Table 4-6.

5.1.5 Cycle-Specific Parameter Determination

The SAS2H code requires as input a thermal power for each defined irradiation period (or "cycle"), as well as the temperatures and densities of all materials (which may themselves be fixed or be cycle-dependent). As discussed in Section 4.3, cycle-average values are determined for parameters like

material temperatures, water densities, and thermal power levels, consistent with the Reference 3.1.1 SAS2H benchmark (i.e., code bias determination) analyses.

The (average) fuel material thermal power levels, in MW/MTU, are determined for each cycle by dividing the increase in burnup that occurs over that cycle (in MWd/MTU) by the duration of the cycle (in days). The beginning and end burnup levels for each cycle (i.e., assembly irradiation period), along with the start and end dates for those cycles, are provided for each loaded assembly in Reference 3.2.3 and in Attachment B of this calculation. From this data, the duration and burnup increment (or increase) for each cycle is readily determined. After the cycle-specific, assembly-average thermal power levels are determined for each assembly, they are multiplied by the Table 5-2 axial profile factors to yield local fuel thermal power levels for each axial zone of each assembly, as discussed above in Section 5.1.3. The resulting local, cycle-average thermal power level is used in the individual SAS2H analysis that applies for the corresponding axial zone of corresponding assembly. This process is repeated for every cycle (or assembly irradiation period) that applies for the given assembly.

After the thermal power levels are determined for each assembly axial zone and each irradiation cycle, the corresponding material temperatures and moderator (water) density must be determined. The first step in this process is to determine the water temperature for each axial zone. The water temperatures at the bottom and top of the assembly fuel zone are simply equal to the reactor inlet and outlet temperatures shown for each reactor cycle in Table 4-4. The temperatures for the intermediate elevations are determined by assuming a cosine distribution for the axial distribution of assembly thermal power, as is recommended in Reference 3.2.12. Thus, the energy deposited into the water—and thus the increase in water temperature with axial elevation—is assumed to be proportional to the average power level times a cosine function, where the power input is maximum at the axial center of the fuel and approaches zero at both ends. Using this approach, an axially-dependent water temperature profile is determined, along with the resulting average water temperature for each of the 18 defined axial zones (for the cycle in question). This axial water temperature profile is discussed in more detail in Section 5.3.5.

After the water temperature is determined for each axial zone and each cycle, the water density is determined based upon an assumed reactor pressure of 2250 psi, interpolating from the density-versus-temperature data given in Table S2.5.2 of Reference 3.2.6.

After the water temperature is determined for each assembly zone and each cycle, the corresponding fuel temperature is determined. Figure 9 of Reference 3.2.12 presents the effective (average) fuel temperature as a function of linear thermal power of the fuel rod (in W/cm). The figure shows a temperature of 300 ^{o}C at zero power, which is assumed to correspond to the associated water temperature. The plot shows a temperature of ~675 ^{o}C at a rod axial thermal power of 250 W/cm. Thus, it is assumed that the local fuel temperature (for each axial zone) is equal to the local water temperature plus 375 ^{o}C times the local rod axial thermal power in W/cm. The axial thermal power for one rod is determined from the local assembly thermal power level (in MW/MTU), the axial uranium loading (in MTU/cm) for the assembly in question, and the number of fuel rods in the assembly.

After the fuel temperature is determined, for each axial zone and each cycle, the corresponding cladding temperature is calculated by assuming that the local cladding temperature increment is given by 25% (i.e., 1/4) of the temperature difference between the local water and the local fuel temperature, as discussed in Section 4.3.

After the cycle-average material temperatures (and water density) are determined, they are entered into the SAS2H input files through the initial material descriptions—or through the use of the "tmpfuel", "tmpclad", "tmpmod", and "h2ofrac" commands for subsequent cycles. The cycle-average soluble boron concentrations (for all 18 zones of each given assembly) are taken directly from reactor cycle data in Table 4-4. The boron concentration for the first assembly irradiation cycle is defined by the (borated) water material composition description. A "bfrac" command is used to adjust the boron concentration for subsequent irradiation cycles.

As discussed in Section 4.3, the analyses assume the SAS2H-default boron concentration "letdown function", where the boron concentration drops linearly from 1.9 times the cycle-average value (at cycle start) to 0.1 times the cycle-average value (at cycle end). If the number of cross-section updates per cycle exceeds one (i.e., if the "nlib/cyc" parameter is greater than 1), then SAS2H will automatically calculate an average boron concentration for each resulting sub-cycle, based upon this assumed letdown function.

The second table in Attachment B of this calculation shows which reactor cycles correspond to each irradiation cycle for each individual assembly. This information is necessary to use the Table 4-4 data correctly in determining the cycle-average temperature, density, and boron concentration values for each individual assembly.

Performing the calculations discussed above for every cycle and for every axial zone of every loaded assembly in each MSB would be very cumbersome due to the very large number of cases involved. For this reason, the SASIGEN code was developed to create SAS2H input files using an automated process (which requires a much smaller quantity of user input data). The details of how the SASIGEN code performs the calculations and functions above is given in Section 5.3.

5.1.6 Modeled Light Elements

In general, various light element masses (for materials within the assembly but outside the spent fuel material) are specified in SAS2H fuel depletion analyses, despite the fact that these light elements have little or no effect on the calculated spent fuel isotopic concentrations. A generic set of light element masses are assumed for all of these SAS2H fuel depletion analyses. These masses are presented in Table 5-3. This is the same "typical" set of light element masses that are shown (and modeled) for the Calvert Cliffs and H.B. Robinson SAS2H benchmark cases in Table 17 of Reference 3.2.12. These same light element masses were modeled in the corresponding SAS2H benchmark (code bias) analyses presented in Reference 3.1.1. Although these light elements are not expected to have any measurable impact on the SAS2H spent fuel composition results, they are modeled to maximize consistency with the benchmark analyses upon which the determined SAS2H code bias is based.

Table 5-3 Light Element Masses Modeled in SAS2H Analyses

Element	Modeled Mass (kg/MTU)[25]
O	135
Cr	5.9
Mn	0.33
Fe	13
Co	0.075
Ni	9.9
Zr	221
Nb	0.71
Sn	3.6

5.2 SAS2H Path-B Model Methodology

SAS2H performs two sets of neutronics calculations to determine neutron spectrum and weighted average cross-sections. The first calculation is based on an infinite array of fuel rods, based on the fuel pellet O.D., cladding I.D., cladding O.D., and rod pitch that apply for the assembly in question. Then a second calculation is performed to account for significant features in the fuel rod array (such as water filled guide tubes or neutron absorber rods) that significantly perturb (or affect) the overall assembly neutronics. SAS2H is a 1-D code, which performs its neutronic calculations using an infinite-height concentric cylinder model geometry. Thus, the available mechanism for modeling these assembly array features is to place them at the center of this second (path-B) model and smear the fuel rods around the feature into an effective, homogenous material containing water, cladding, and fuel. This mixture, however, is more than just a mixture of water, clad, and fuel, in that weighted cross-sections for the three main constituent materials (calculated with the initial infinite fuel rod array model) are applied. In the SAS2H input files, this special fuel rod array mixture is always referred to as Material "500".

There are often multiple occurrences of these array features within the entire assembly (such as the eight guide tubes and one instrument tube present in the Fuel Type G1 assembly array, as shown in

[25] Taken from Table 17 of Reference 3.2.12. The values shown above are entered directly into the SAS2H input file, as the uranium mass basis for each SAS2H model is exactly one MTU.

Figure 5). The path-B model does not consist of the analyzed array feature surrounded by all of the assembly's fuel rods, as this would be the equivalent of having only one such feature (e.g., guide tube) in the entire array. Instead a number of fuel rods equal to the total number of assembly fuel rods divided by the number of features (of the type that is modeled) is modeled around the feature at the center of the path-B model. For example, for a G1 assembly with 208 fuel rods and 9 (water-filled) guide/instrument tubes, a guide tube would be placed at the center of the path-B model, and a homogenous mixture (material "500") representing 23.11 (208/9) fuel rods would be placed around it. This more accurately represents the collective proximity of the fuel rods to the nearest guide tube (or other features) in the assembly array, and thus more accurately estimates the neutronic characteristics within the array.

The path-B model consists of a set of concentric cyclinders, each with a given inner and outer radius, and completely filled with a given material (i.e., water, guide tube material such as Zircaloy, neutron absorber material, or material "500"). Note that material "500" only occurs in one of the annular zones. At the center of the model is the analyzed assembly feature itself, such as a water-filled guide tube, or a neutron absorber rod. For the inner path-B model zones that describe the array feature itself, the zone radii are simple to determine, as they simply reflect the radial dimensions of the array feature itself (such as the inner and outer radius of a guide tube). These radii can be directly obtained from the user's physical description of the array feature (e.g., the physical description of an annular neutron absorber rod, etc…). This simplicity is due to the fact that exactly one array feature is modeled, and the fact that these features are already cylindrical in shape (generally). Outside the inner part of the path-B model that reflects the analyzed array feature itself, things are more complex since square geometry features must be made cylindrical (through the use of "effective" radii) and multiple/fractional numbers of external features (such as fuel rods) are being modeled.

The first path-B model zone outside the zones that describe the analyzed array feature itself is the water annulus that represents the remaining water in the (square) array unit cell that surrounds the feature. The area of the array unit cell is the square of the rod pitch. The outer radius of the water unit cell zone is set so that the resulting cylinder has an area that is equal to that of the square unit cell, i.e., equal to the square of the fuel rod pitch. The inner radius of this annular zone has already been determined, as it is simply the outer radius of the modeled array feature (e.g., guide tube, etc…). Also note that the area of the annulus will equal the (square) unit-cell area outside the (cylindrical) array feature, because if the area of the cylinder (inside this O.R.) is equal to the full unit cell area, then the area of the annulus (i.e., the area of the cylinder minus the area of the array feature) is clearly equal to the area of the unit-cell water outside the feature (i.e., the area of the unit cell square minus the area of the feature).

For all path-B models, the next annular zone (outside the unit cell water zone) is the material "500" zone that represents the sub-set of fuel rods that are associated with each array feature (e.g., the 23.11 fuel rods discussed in the example above). The area of the annular material "500" zone is set to equal the collective area of all of the unit cells of the associated fuel rods. Thus, the area of the material "500" annulus is equal to the square of the fuel rod pitch, times the number of fuel rods in the assembly, divided by the number of array features (of the type being analyzed) in the assembly. In the Type G1 assembly example, the area of the annulus would be 23.11 times the square of the rod pitch. To determine the outer radius of the material "500" zone, a cylinder with an area equal to that of one array unit cell plus the number of fuel rod unit cells in the material "500" annulus is considered. This is because the cylinder in question would include the central unit cell (containing the analyzed feature)

along with the material "500" annulus. Thus, in the Type G1 assembly example, the cylinder would have an area equal to 24.11 times the square of the rod pitch. Thus, the outer radius of the material "500" zone is given by:

$$R_{500} = \sqrt{\left[1 + \left(\frac{N_{Rod}}{N_{Pert}}\right)\right] * \left(\frac{P^2}{\pi}\right)}$$

where "R_{500}" is the outer radius of the material "500" zone, "N_{Rod}" is the number of fuel rods in the assembly, "N_{Pert}" is the number of features (perturbations) of the type being analyzed in the path-B model that are present in the actual assembly, and "P" is the fuel rod pitch.

Generally, a water layer is modeled around the outside of the material "500" zone. This layer represents the water that lies between fuel assemblies when they are in the reactor. The outer radius of this layer is such that the area of the resulting cylinder is exactly equal to the square of the reactor assembly effective pitch divided by the number of analyzed features present in the assembly. In some cases, where multiple perturbation features are present, and only one is being modeled, an outer layer like this will represent the collective area of the features that are not being modeled. For example, in a case where neutron absorber rods and water-filled guide tubes are both present, and the absorber rod is being modeled in the center of the path-B model, an external water layer, calculated on the basis of the assembly pitch, will represent not only the water between the assemblies (in the reactor), but it will represent all of the water in the guide tube unit cells. This is because the presence of the guide tubes will reduce the number of fuel rods in the assembly (for each absorber rod) and will thus reduce the outer radius of the material "500" zone. The outer radius of the external water layer, however, will remain the same, as it is purely a function of the assembly pitch. The result is that the thickness of the external water layer will increase, due to the presence of the guide tubes (as opposed to additional fuel rods). The extra water in the outer water layer represents the water in the guide tubes (and their external unit cells). This extra water models the effect of a guide tube near the edge of the assembly section that is associated with each absorber rod.

The Palisades assembly path-B models differ somewhat from those of typical PWR assemblies, however, due to the presence of eight solid Zicaloy guide bars around the perimeter of the assembly. In these analyses, these eight guide bars are modeled as a solid, equal area ring around the material "500" zone. The area of this ring is equal to that of the eight guide bars, divided by the number of modeled features. A ring of water, whose area corresponds to that of the water between assemblies, plus any guide/instrument tube array cells not modeled as the central feature, lies outside this solid Zircaloy ring. This is described further in Sections 5.3.5 and 6.2.1.

The path-B model zones described above (and the methods for determining their radii), cover all of the zones generally present in most path-B models. In the relatively rare case of the partially-inserted control blades, a somewhat more involved path-B model is constructed. The development of this model is described in Section 5.4.1.

Some cases involve complications that can not be rigorously treated by the SAS2H path-B model. In these cases, approximations must be made. In the case of Assembly Type G3 (Figure 7), for example, there are 8 guide tubes, instrument tube, and 6 burnable poison rods to be modeled—for a total of 15 potential features. As discussed in Section 6.2.4, the SAS2H analyses treat this by modeling 15 features containing neutron absorber rods with the area of the rod zones (absorber and cladding) reduced to 6/15 of their nominal value. The radii of the inner zones of the path-B model are reduced accordingly. The guide tube zone radii are not adjusted, and the remaining zones of the path-B model are calculated normally, using the methods discussed above. With this approach, a sort of "average" feature (6/15 absorber rod, 9/15 pure water) is modeled at the center of the path-B model. This general treatment is consistent with the approach employed in References 3.2.12 and 3.1.1.

Also, as discussed in Section 4.1, sometimes significant array perturbation features are only present for part of the assembly's irradiation history. SAS2H does allow for the path-B model to be changed for different defined irradiation periods, but it is cumbersome. There are two options. If the "mxrepeats" card is left out, or set to a value other than zero, then a single line of input describing the path-B model is entered, and this description is assumed to apply for all cycles. The other option is setting "mxrepeats" to zero, and entering a separate path-B model card (or line), not only for every defined reactor cycle, but for every cross-section update period. Thus, the total number of lines equals the number of cycles times the value of the "nlib/cyc" parameter. Thus, the number of lines can get quite large, but this is necessary if any changes in the path-B model are to be analyzed. Generally, all of the zones (and radii) necessary to describe the array feature (such as an absorber rod) are entered in a path-B model line, and this line is copied as many times as necessary. For the sub-cycles when the absorber rods are absent, the absorber rod materials (absorber, clad, etc…) are simply all changed to water.

Additional details of the construction of the Palisades assembly path-B models are discussed in 5.3.

5.2.1 SAS2H Path-B Model Selection

As discussed above, in several cases there are multiple features that could be modeled. Several different approaches to modeling these features were considered:

1. Model both types of features
2. Model each feature and take the worst result
3. Move one of the features to the outside of the path-B model.

The approach taken was decided on a case-by-case basis, considering the significance, number, and placement of the feature. One such example is the G3 assembly, discussed in Section 6.2.4.

5.3 Use of the SASIGEN Computer Code

All runs are prepared by means of the SASIGEN Code (Reference 3.2.18), a BFS Category 2, internally developed computer program. This is done for two reasons. First, the present characterization of the spent fuel in the loaded Palisades MSBs requires the use of 7776 SAS2H runs (18 MSBs x 24 assemblies/MSB x 18 axial zones/assembly) in addition to the runs needed to characterize the extra fuel rods described in Section 6.6. The construction of this number of input files would be extremely time-consuming and potentially error-prone. Second, in order to allow for the checking of this number of input files, it is beneficial to make use of the BFS software process—doing a substantial portion of the methodology-checking during the software validation phase rather than at the end of the performance of a large number of analyses.

In several cases involving limitations of the SASIGEN code, the SAS2H input files are subsequently edited. This is discussed in Section 5.4.

5.3.1 Description of the SASIGEN Code

SASIGEN (**SAS I**nput **Gen**erator) is a computer code used to automate the preparation of SCALE SAS2H input files to enable the performance of isotopic buildup and depletion calculations. The user supplies an input file with various fuel parameters (physical and operational) and the code produces the corresponding SAS2H input file. SASIGEN is a BFS Category 2, internally developed computer program. The code runs in a DOS shell on Personal Computers running under various versions of the Windows operating system. Each execution of SASIGEN is intended to model a single loaded MSB, although it is also possible to model a smaller number of assemblies than a fully-loaded MSB.

5.3.2 SASIGEN Code Inputs

The input file consists of a title card, a desired decay (or shipping) date, a ΔT_{clad} fraction (described below). The input file also contains one set of data for each assembly to be modeled. The data for each

assembly is in turn broken into one row of assembly-specific input and two rows of cycle-specific data for each cycle through which the assembly has been irradiated.

SASIGEN accepts the following inputs.

- General Problem/Case Information
  - Date to which fuel is to be decayed (Shipment Date)
  - ΔT_{clad} fraction, fraction of ΔT_{fuel} used to approximate ΔT_{clad}. (Both are linear functions of local power.)
  - Cask number
  - Assembly number, corresponds to location in cask
- General Assembly Information (up to 74 sets allowed)
  - Fuel assembly type – integer format
  - Initial ^{235}U enrichment percentage
  - Number of cycles for assembly (from 1 through 10)
  - Beginning of cycle (BOC) burnup for each cycle
  - End of cycle (EOC) burnup for each cycle
  - BOC and EOC date for each cycle
- Fuel and Reactor Operating History Details
  - Fuel physical geometry details:
    - Assembly initial uranium mass, MTU
    - Rod pitch, cm
    - Fuel pellet OD, cm
    - Clad OD, cm
    - Clad ID, cm
    - Number of pins per assembly (used to determine fuel volume & density, rod power, and included in SAS2H input file)
    - Number of pins to be assumed in constructing the SAS2H path-B model
    - Active fuel rod length, cm
    - Number of additional material composition lines entered
    - A flag to indicate whether the additional material composition lines are to be appended by the moderator temperature and the word ‘END’. This feature allows for the direct inclusion of a temperature or for the entering of material lines that go beyond a single physical 80-character line.
    - Assembly pitch, cm
    - Guide tube parameters

- Number per assembly
- ID, cm
- OD, cm
- SAS2H material number for guide tube
- M_1, mixture number of ring 1 (if used)[26]
- R_1, radius of ring 1 (if used)
- M_2, mixture number of ring 2 (if used)
- R_2, radius of ring 2 (if used)
- Mouter, mixture number of outer ring
- Mextra, mixture number of extra ring immediately inside extra ring (Enter 0 if an extra ring is not desired.)
- Rextra, cm, radius of extra ring immediately inside extra ring (Value is not used if Mextra is 0, but must be entered nonetheless.)

o Moderator temperature, each cycle, °F
  - T_{in}
  - T_{out}

o Average Boron Concentration, each cycle, ppm

o Additional material composition lines, if any

A thorough description of the inputs is provided in References 3.2.18 and 3.2.20.

5.3.3 Description of SASIGEN Output

The code output is provided in two different fashions. First, the input data and intermediate calculated results are displayed in the output file corresponding to the SASIGEN input file name. Second, the code outputs a SAS2H input file for each axial zone of each assembly in the canister being modeled. These input files are formatted to be suitable for execution by the SAS2H code. Examples of each are provided in the Sasigen User's Manual, Reference 3.2.20.

In addition, SASIGEN produces a batch file to facilitate the DOS execution and organization of all of the cases for which input files are prepared.

[26] Optional ring 1 and ring 2 fall inside the "Guide Tube" inner radius. These rings are included to allow an analyst additional flexibility for modeling more complex features and need not be utilized.

5.3.4 SASIGEN Code Requirements and Design Structure

The formal SASIGEN functional requirements are presented in Reference 3.2.18. Reference 3.2.18 also presents a SASIGEN flow chart, variable and subroutine descriptions, run instructions, and ranges and limitations on code inputs and outputs. These items are summarized below, and discussions are provided when applicable to this current calculation package.

The SASIGEN code consists of three modules. Sasigen, the main code, controls the high-level looping operations and calls the other two modules; the main code also reads and regurgitates the user input file. Scaling_prep is the routine used to calculate the values of the various intermediate and final parameters to be used in generating the final output; Scaling_prep also prints these intermediate parameters for troubleshooting and debugging purposes. Sasdeck_print is the routine that produces each of the SAS2H input files.

Sasigen

scaling_prep	Called once by Sasigen for each axial zone of each assembly (i.e., once for each SCALE 4.4 input file to be produced).
1, Jcycle	Loop established over the number of cycles for the given assembly (iassynum) and axial zone (kzone)
sasdeck_print	Called once by Sasigen for each axial zone of each assembly (i.e., once for each SCALE 4.4 input file to be produced).
1, Jcycle	Loop established over the number of cycles for the given assembly (iassynum) and axial (kzone)

The looping and calling logic can be seen in Figure 22.

5.3.5 SASIGEN Modeling Methodologies and Approaches

SASIGEN makes use of three built-in axial power profiles—the limiting axial burnup profiles taken from Reference 3.2.8. As described in that reference, these profiles were taken from a database of 3169 axial burnup profiles from five different PWR fuel types. The reference work considered twenty different PWRs and 105 operating cycles and is intended to account conservatively for changes in end effect reactivity with burnup. Based on an assembly's average final burnup, SASIGEN makes use of the normalized axial burnup profile data presented in Table 5-2.

Making use of the appropriate axial power profile, local burnup values are then determined for each of the 18 axial regions. This is taken from the following:

$$BU_{local} = cycleBU_{i,j} \times profile_{k},$$

where

$$cycleBU_{i,j} = BU\_EOC_{i,j} - BU\_BOC_{i,j}$$

Local powers are then found from these burnup values and from the cycle startup and shutdown dates. The analyses model the bounding 18-zone axial burnup profiles from Table 5-2. It is assumed that the resulting axially-varying isotopic compositions are bounding (i.e., more reactive) for any given whole MSB. In the rare event of a single outlying assembly profile, it is recognized that the conservative treatment of the remaining twenty-three assemblies will more than account for the single outlier.

The average moderator temperature is determined, based on the integration of a cosine power shape. The following expression is taken from Reference 3.2.12.

$$T(z) := T_{in} + \frac{(T_{out} - T_{in})}{2} \cdot \left(1 - \cos\left(\frac{\pi \cdot z}{H}\right)\right)$$

Next, the fuel temperature at each of the axial locations in the core is determined from the axial power and the moderator temperature. As discussed in Reference 3.2.12 (page 28), the temperature can be taken from a conservative linear fit of the Obrigheim data presented; this is also discussed in Section 5.1.5.

The clad temperature is then determined at the midpoint of each of the 18 axial zone locations. The clad ΔT is determined from a user-input fraction of the fuel ΔT. The clad temperature is then given by $T_{mod} + \Delta T_{clad}$. As discussed in Section 4.3 (assumption 1), this fraction is conservatively taken to be 25%.

SASIGEN then constructs a SAS2H input file based on the user-specified inputs and the above-calculated values. The materials and nuclides are based on the descriptions in Section 5.1; these are generally consistent with the approaches taken in References 3.2.12 through 3.2.16.

A fuel composition is determined and set up as material 1. The UO_2 density is obtained from the ratio of mass and volume.

$$V_{fuel} = Npins \cdot (\pi \cdot R_{pin}^2) \cdot H_{fuel}$$

$$\rho_{fuel} = \frac{M_{assembly}}{V_{fuel}} \cdot \frac{270}{238}$$

where H_{fuel} is the actual height of the fuel, R_{pin} is the pellet diameter, and Npins is the input number of fuel pins present in the fuel assembly. Volume fractions are found for ^{234}U, ^{235}U, ^{236}U, and ^{238}U making use of the user-supplied enrichment value. As in Reference 3.2.12, the ^{234}U and ^{236}U percentages are approximated from the following expressions.

^{234}U wt % = 0.0089 x ^{235}U wt %

^{236}U wt % = 0.0046 x ^{235}U wt %

Calculated fuel, moderator, and clad temperatures are included in the material and nuclide specifications. As discussed in Section 5.1.5, cycle average values are utilized. Water densities are

interpolated from the values provided in Reference 3.2.6 based on an assumed reactor pressure of 2250 psi. A fuel length is found so as to yield a total assembly initial loading of one metric ton. As discussed in Section 5.1.1, the library update frequency is set to the minimum value required to ensure that there is at least one code subcycle (and hence one library update) for every 5000 MWD/MTU of burnup. Final decay times are determined based on the end date of the final cycle and the user-specified shipment date.

A path-B model is included in each SAS2H input file and is based on the general model shown in Figure 23. The one-dimensional (R-Z geometry) model consists of seven or eight concentric rings describing a feature surrounded, by water, fuel, and other optional materials. The two innermost rings can be viewed as optional and can be filled with water to effectively remove them from the model. The rings immediately inside and immediately outside the "guide tube" ring must be water but are of arbitrary size. The "guide tube" shown in the figure need not be an actual guide tube and can be composed of any of the materials defined in the given case. Outside the "Material 500" fuel ring is an optional, outer ring that can be composed of any defined material. Finally, there is an outermost ring of arbitrary size that can also be composed of any of the defined materials.

In the Palisades models, several approaches are applied consistently throughout the fuel assembly types. Others are modified from one assembly type to another. The chief examples of modeling techniques used for all assemblies include the treatment of assembly guide bars and the modeling of a water gap at the outside of the path-B model. Each Palisades fuel assembly includes, in the outermost fuel rod row, a total of eight guide bars. Each guide bar takes the place of one fuel pin, and the guide bars are characterized by an "effective radius" as presented in Table 4-5. The total area of guide bars in a single assembly is therefore equal to eight times the area of a single guide bar, given by:

$$A_{guide\_bar} = \pi \cdot r^2_{effective}$$

and the area associated with a path-B model is equal to eight times the guide bar area divided by the number of features being represented by a particular path-B model. The outer radius of the "extra ring" is then given by this guide bar area per modeled feature:

$$r_{extra} = \sqrt{((A_{500} + A_{guide\_bar} / N_{pert}) / \pi)},$$

where N_{pert} is again the number of features, and A_{500} is the total area per modeled feature falling within the fuel (material 500) outer radius (consistent with the formula and discussion presented in 5.2).

Finally, with regard to the water gap at the outside of the path-B model, the area of this outer ring effectively accounts for two things. First, this outer ring accounts for the areal difference between the rod pitch squared times the total number of pin lattice locations (whether occupied by fuel rods, poison rods, guide tubes, or instrument tubes) and the square of the assembly pitch. Due to the use at Palisades of cruciform control blades, it is necessary to develop an effective assembly pitch, which accounts for the narrow gap on two sides of the assembly and the wide gap that falls on the other two sides. From Reference 3.2.2 the wide water gap (i.e., the control blade channel) is 2 x 0.464 cm = 0.928 cm. The same reference also provides the narrow gap, 2 x 0.133 = 0.266 cm. The effective assembly pitch is then given by N_{rods} per row x pitch plus the average of the narrow and wide gap thicknesses:

$$P'_{assy} = n_{rods/row} \cdot P_{assy} + \frac{gap_{narrow}}{2} + \frac{gap_{wide}}{2}$$

For a rod pitch of 1.397 cm, the effective assembly pitch is 21.552 cm.

Second, the outer ring accounts for any additional water inside the fuel assembly that is not associated with a particular modeled object occupying a rod pitch location. For example, when the modeled feature is a poison rod and there exist additional guide tubes that are not explicitly modeled, SASIGEN automatically places the water associated with these guide tubes in the outermost ring of the path-B model.

Figure 22 – SASIGEN Flow Chart

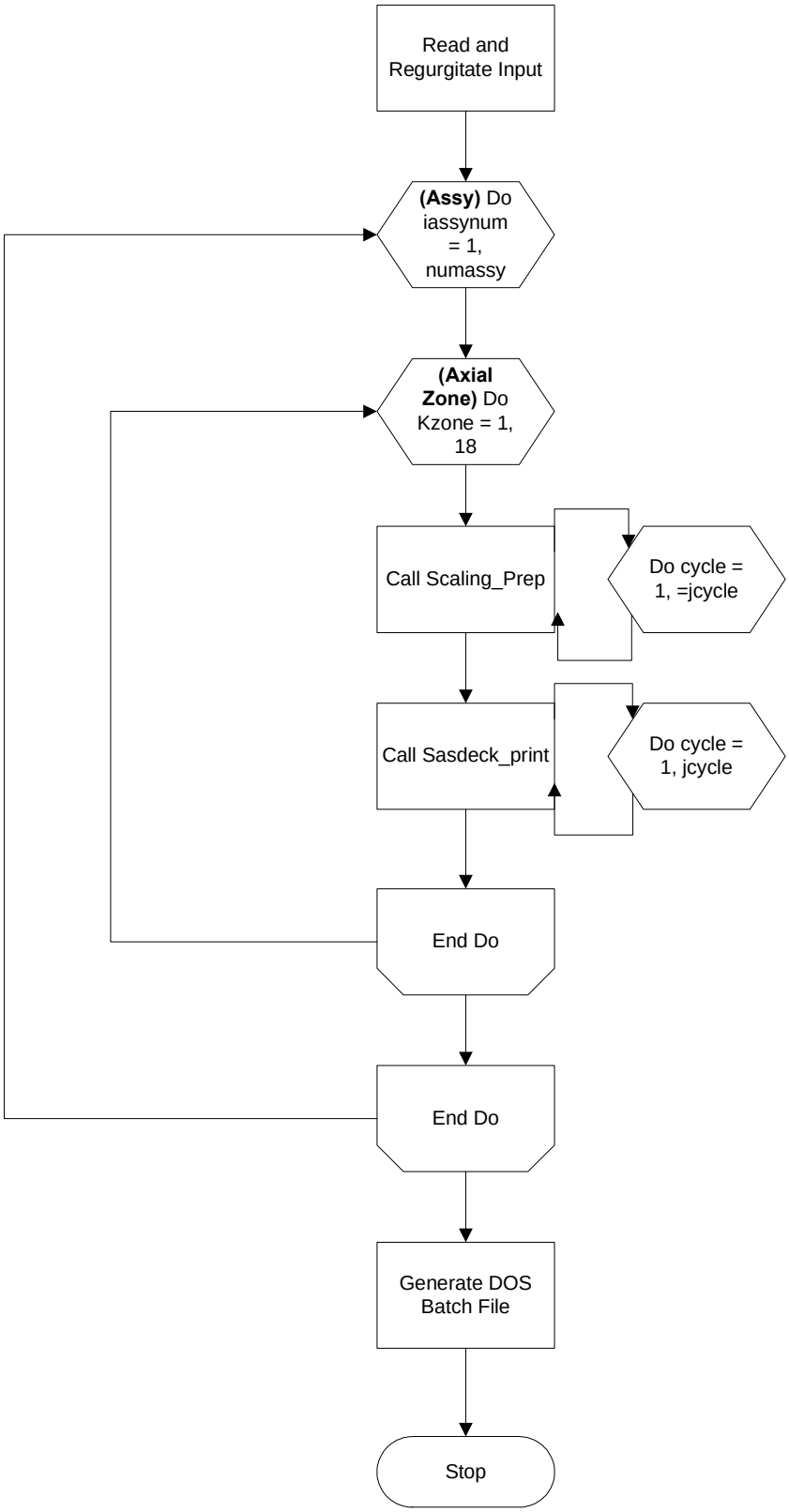
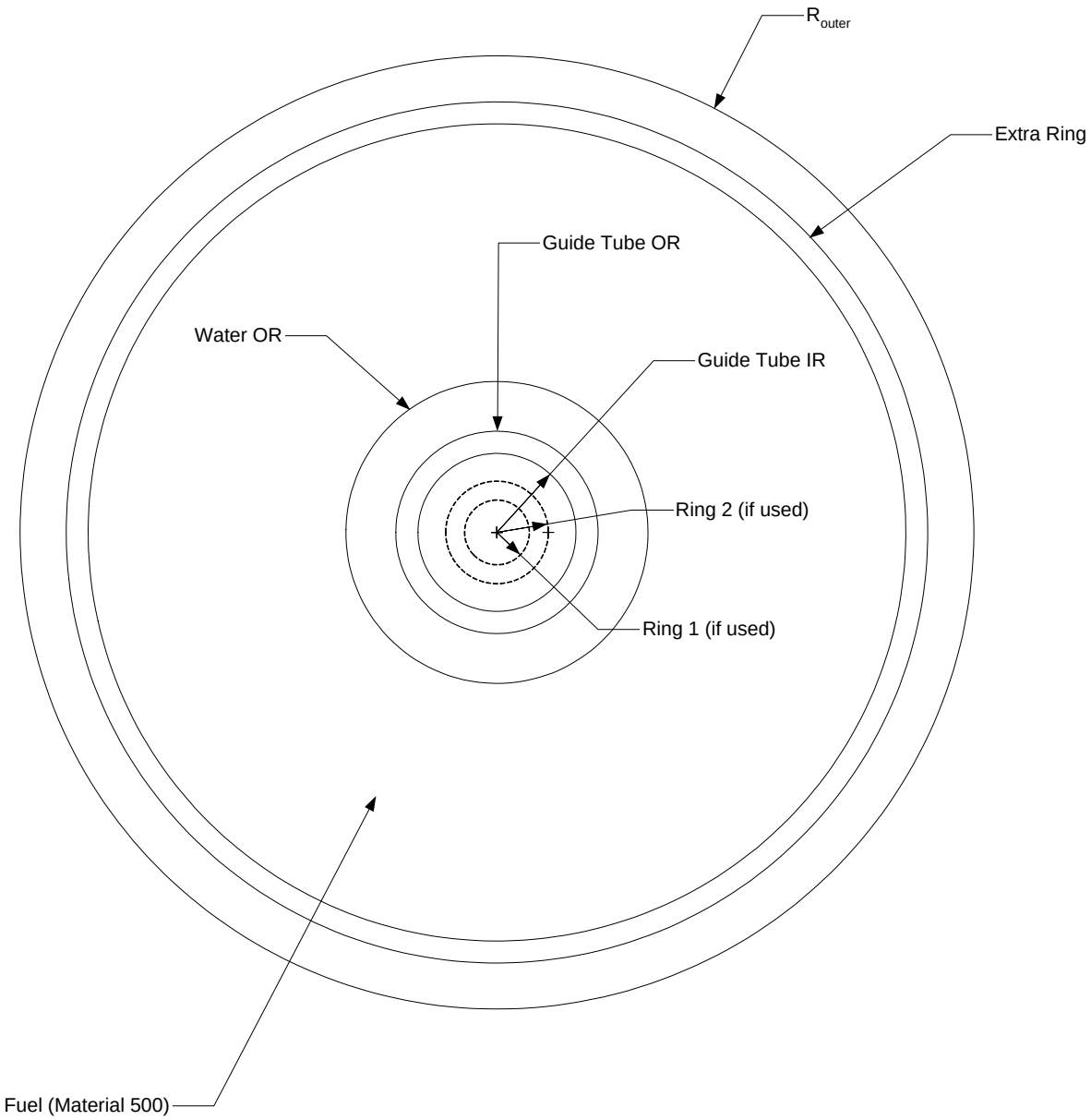


Figure 23 – SASIGEN Path-B Model Geometry (General)



5.4 Subsequent Hand-Editing of SAS2H Input Files

In several cases the SAS2H input files are subsequently edited. In general, this is done when the items being modeled could not be fully automated through SASIGEN. Although the SASIGEN code offers a significant degree of flexibility for modeling various fuel types, insert configurations, and plant operating details, situations remain where it is necessary to make changes to individual SAS2H input files. Details requiring additional hand treatment include situations where inserts vary with axial position or with operating time as well as cases where fuel has been reconfigured during its operating history.

There are three categories of details where such hand edits were required. First, in the case of the hafnium absorbers loaded into I1H assemblies following a number of cycles of operation, the SAS2H input files are subsequently hand-edited in order to produce the required cycle-dependent and library update-dependent path-B lines. Second, in treating the effects of partially-inserted control blades, it is necessary to make use of cycle-varying changes to the input files; again, this requires the use of hand-editing. Third, the G2, H2, I3, and I1H fuel types, as described in Sections 6.3.6, 6.3.9, and 6.3.12 require a hand edit to allow for the modeling of the reduced-density zircaloy used to represent the materials in the combined clad/gap space. The specific effects being treated and the changes made are described in Section 6.7.

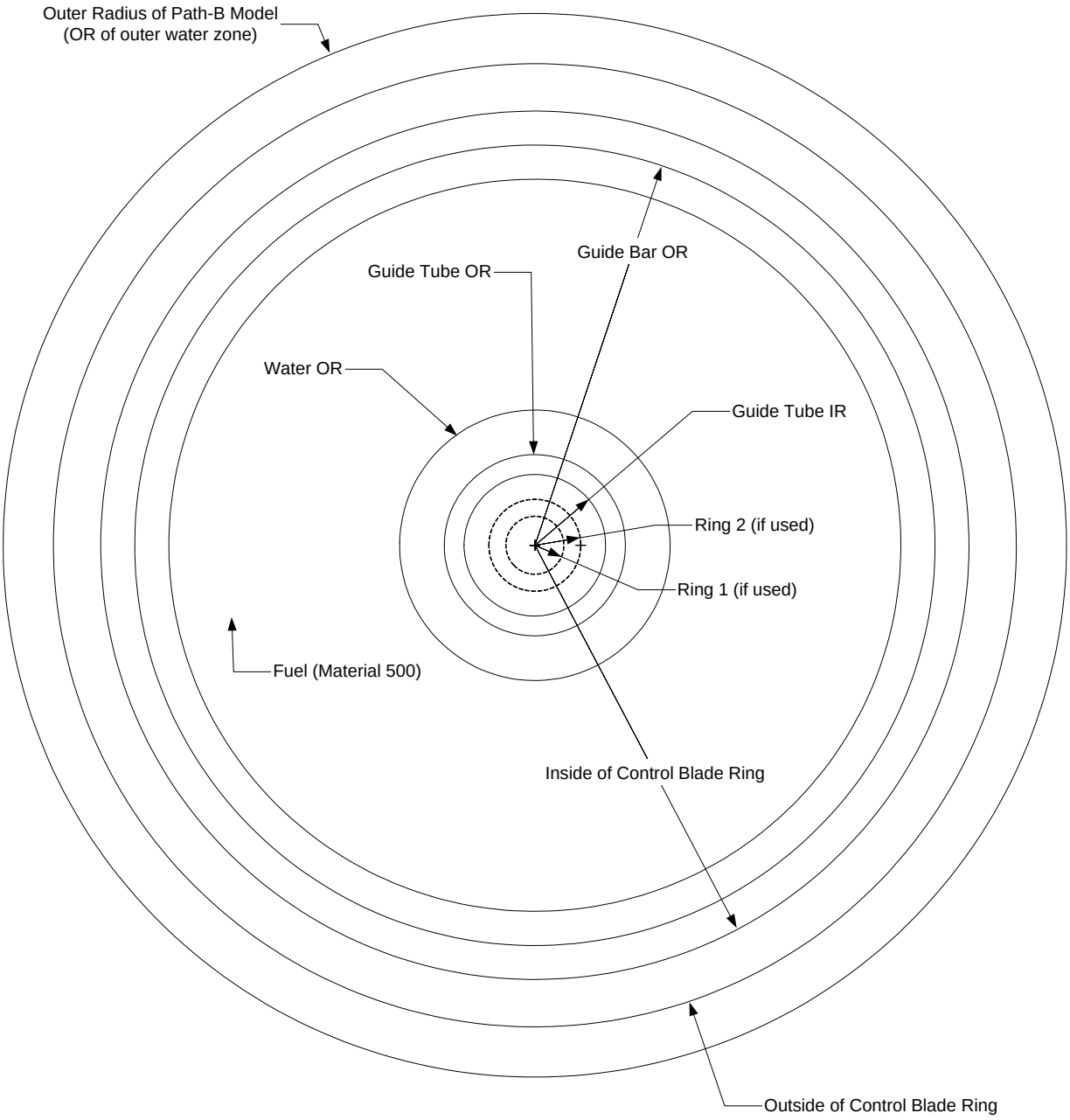
5.4.1 Modeling of Partially-Inserted Control Blades

The path-B model zones described above (and the methods for determining their radii), cover all of the zones generally present in most path-B models. In a small number of cases—the Palisades assemblies adjacent to partially-inserted control blades—an external feature (the control blade) is present. In this case, the control blade is modeled through the addition of two additional annular zones which are placed just outside the zircaloy ring representing the guide bars. The first of these additional rings has a thickness equivalent to the water channel between the fuel assembly and the control blade. The second ring represents the control blade itself, and is composed homogenously of Ag-In-Cd and 304 SS in the quantity and volume fraction required to conserve the amounts of these control blade materials. Thus, the additional zone has an overall area equal to that of the contributing area of the control blade divided by the number of array features. The contributing area of the control blade is determined by dividing the full cruciform control blade area by the number of assemblies sharing that object. Since four assemblies surround a control blade, one fourth of the full cruciform blade's area is considered in constructing a path-B model. Finally, an outer water ring is included with a thickness equivalent to the water channel falling outboard of the control blade. The setup of this path-B model is presented in Figure 24.

The above modeling approach effectively models a half-thickness control blade on all four sides of the assembly, as compared to the physical configuration where the full-thickness blade lies on two sides of the assembly. Such an approach is necessary because SAS2H (and its associated path-B model) requires radial symmetry. The above approach is conservative, however, for the following reasons. The

presence of neutron absorber materials generally increases reactivity due to neutron spectral hardening and the associated increase in plutonium production in the fuel. Moving neutron absorber material from the back half of the blades present on two sides of the assembly, and moving it over to the two other (unoccupied) sides of the assembly will increase the overall "effectiveness" of the neutron absorber material. This is especially true given the fact that the control blade is already quite "black" to neutrons, and the absorber material on the back side of the blade would have had relatively little effect. The effectiveness, or "worth" of the absorber material is thus substantially increased by placing it in close contact with the other two sides of the assembly. It should also be noted that, although additional water is modeled on the far side of the control blade material ring, its presence (or thickness) will have little effect on the neutronics, or on the fuel depletion analysis in general.

Figure 24 – SAS2H Control Blade Path-B Model Geometry



6. CALCULATIONS

6.1 SASIGEN Code Generation of SAS2H Path-B Models

As discussed in Section 5, a path-B model is defined for each assembly type in the SAS2H analyses. Row 5 of the SASIGEN input file (as well as the equivalent lines for subsequent assemblies) provides the information to be used in the construction of the path-B model to be included in the SAS2H cases for the first assembly in the MSB. The user-supplied data in this row is shown below; the "(1)" denotes the first assembly. Path-B inputs for subsequent assemblies are provided in the same format.

assypitch(1) – Assembly-to-assembly pitch for first assembly, cm

Ngt(1) – Number of guide tubes per assembly 1

GTir(1) – Inner radius of guide tube in first assembly, cm

GTor(1) – Outer radius of guide tube in first assembly, cm

Mgt(1) – SAS2H guide tube material number (first assembly)

Mring1(1) – Mixture number of ring 1 in first assembly.

Rring1(1) – Radius of ring 1 for first assembly, if used, cm.

Mring2(1) – Mixture number of ring 2 in first assembly

Rring2(1) – Radius of ring 2 in first assembly, cm

Mouter(1) – Mixture number of outer ring in first assembly

Writemodtemp(1) – Flag indicating whether the moderator temperature is to be included at the end of the material compositions in the SAS2H input files for assembly 1

Mextra(1) – Mixture number of extra ring immediately inside the outer ring in first assembly (Enter 0 if an extra ring is not desired.)

Rextra(1) – Radius of extra ring immediately inside the outer ring in first assembly, cm (Value is not used if Mextra is 0, but must be entered nonetheless.)

All path-B models prepared by the SASIGEN code consist of 8 concentric rings. The positions of the various rings that can be modeled in the Path-B model are shown in Figure 23. If a particular ring is not needed to model a given fuel type, the same mixture number is simply entered for multiple adjacent rings. For example, if there are no features housed inside a guide tube, a "3" is simply entered as the material number for Ring1 and Ring2.

Entering a guide tube radius greater than or equal to GTir(1) will cause the code to override this with a value slightly smaller than Gtir(1). This allows a user simply to maintain a large value (e.g., 100.0) to make use of the code's override capability.

6.2 Construction of SAS Path-B Models

The following subsections in this section describe the treatment and modeling of various features present in the Palisades MSBs.

6.2.1 Treatment of Guide Bars

All of the Palisades fuel assemblies loaded into the MSB's include eight zircaloy guide bars, which replace eight fuel rods in the lattice. As discussed in Section 5.3.5, these are modeled as an additional ring falling just inside the outer ring of the SAS2H model. This ring is filled with zircaloy (the material of the bars' construction) and the thickness of this ring is chosen to preserve the total quantity of zircaloy. This ring is modeled immediately outside the Material 500 fuel region – the ring identified in Figure 23 as the "extra" ring. Table 6-4 presents the calculation of the inner and outer radius used in the path-B model to represent this guide bar ring.

6.2.2 B_4C and Gd_2O_3 Rod Material Compositions

Several of the fuel assembly types include a number of B_4C rods. These exist only in assemblies with no empty guide tubes. Thus, the B_4C rods can be modeled as the feature in the path-B model without guide tubes needing to be modeled as well.

As described in Reference 3.2.2, the poison rod filler is Al_2O_3 inert material. When modeling a feature like B_4C rods with Al_2O_3 inert material, the following extra material setup is used (for 4.7% B_4C in this example):

```
b4c  4 den=3.3634 0.047
al   4 den=3.3634 0.504
o    4 den=3.3634 0.449
```

The numerical inputs for each consist of the given B_4C rod material density of 3.3634 g/cc and the individual density multipliers, based on the atomic weight of aluminum (26.9815 per Chart of Nuclides, 15th ed.), oxygen (15.9994), the stoichiometric ratio of 2/3, and the wt-% of B_4C (4.7%). So, for example, the mass fraction for Al is given by:

$$VF_{Al} = \frac{26.9815}{26.9815 \cdot 2 + 15.9994 \cdot 3} \cdot 2 \cdot (1 - 0.047)$$

Although the three-line version results in a SAS2H input file with a temperature and the word 'end' after each of these lines, a check of the SAS processing makes it clear that the densities are being properly read and interpreted.

As stated in Section 4.1, some of the B_4C rods exist in assemblies with no guide tubes. In this case, the B_4C rods themselves are modeled as the feature in the path-B model. In other cases, the B_4C rods are themselves loaded into guide tubes in the assembly. In this case, both the rod and the guide tube are modeled (concentrically) as the path-B feature. The specific B_4C rod configuration for the various assembly types are detailed in Table 4-6 and discussed in Section 4.1.1.3.

All in all, there are three different concentrations of B_4C in burnable absorber rods: 1.7, 4.7, and 7.7 wt-%. Table 6-1 presents the fuel type, concentration, and poison pellet density for each type of B_4C rod—these items are taken from Reference 3.2.2. The table also presents the aluminum and oxygen density multiplier for each type; these are obtained as in the example shown above.

Several fuel types exist for which no density is supplied in Reference 3.2.2 (nor in Table 6-1). In such cases, the calculated UO2 density is taken from the SAS2H inputs files generated by SASIGEN – that density is calculated by the code as described in 5.3.5.

Several Palisades assembly types contain UO_2 fuel rods that include Gd_2O_3 absorber material, at the weight percentages shown (for each assembly type) in Table 4-6. Reference 3.2.2 gives a Gd_2O_3/UO_2 material density of 10.0602 g/cc for G3 assemblies, and a Gd_2O_3/UO_2 material density of 10.1355 g/cc for H3 and I4 assemblies. No density information is given for the other assemblies that contain Gd_2O_3 rods (i.e., the J2, K2, L2, and L3 assemblies). For these assemblies, the density of the Gd_2O_3/UO_2 material is assumed to equal the density of the UO_2 in the standard fuel rods (calculated by SASIGEN for the individual assembly in question, using the method described in Section 5.3.5).

The Gd_2O_3/UO_2 material is modeled in SAS2H by defining a second fuel material This new material is defined by two individual material lines in the SAS2H input file, one corresponding to UO_2, and one corresponding to an arbitrary material that describes Gd_2O_3. For both materials, the overall density discussed above is specified. For the (arbitrary) Gd_2O_3 material, the volume fraction (as shown in Table 4-6) is also specified. Thus, the UO_2 material is conservatively modeled at full density, despite the presence of Gd_2O_3. The Gd_2O_3 density is then added on top of that, resulting in an actual overall density that is somewhat higher. The arbitrary Gd_2O_3 material specifies "natural" gadolinium (which assumes the SAS2H-default isotopic breakdown) and ^{16}O, and specifies a 2-to-3 atomic density ratio between the two (based on the chemical formula of Gd_2O_3). The resulting material cards are shown below. This material description is treated in SASIGEN by literally entering the lines below into the SASIGEN input file. As SASIGEN does not calculate assembly-specific input to such material lines, a generic, representative temperature of 750 K is entered (and modeled) for all Gd_2O_3 material.

```
uo2   9 den=10.1355 1  750 end
   92234 0.029 92235 3.240 92236 0.015 92238 96.716   end
arbm-gd2o3  10.1355 2 0 1 1 64000 2 8016 3  9 0.04  750 end
```

Table 6-1 B_4C and Filler Density by Fuel Type

Fuel Assembly Type	B_4C Concentration, wt-%[27]	Density, g/cm^3	Al Density Multiplier	O Density Multiplier
A1	1.7	4.0101	.520	.463
E1	7.7	3.3074	.488	.435
G2	4.7	3.3634	.504	.449
H2	4.7	3.3634	.504	.449
I3	4.7	3.3634	.504	.449

6.2.3 Treatment of Guide Tubes and Instrument Tubes

In fuel assemblies where the key path-B features to be modeled are guide tubes (8 tubes) in addition to an instrument tube, the path-B model is constructed to treat the instrument tube, in essence, as a ninth guide tube. Although the dimensions are slightly different, this treatment is more accurate than simply neglecting the instrument tube, which would result in its being modeled at the outer radius of the path-B model. Assembly types where this approach has been used include G1, H1, H1S, I1, I2, and J1. In addition, assembly types G3 and H3 model the instrument tube in conjunction with more than one feature, as in the Gd_2O_3/Guide Tube treatment discussed in Section 6.2.4 below.

6.2.4 Treatment of Assemblies Containing both Gd_2O_3 and Guide Tubes

The Palisades G3 fuel assemblies include two features to be studied: eight guide tubes; and four fuel rods doped with 1% Gd_2O_3. As an additional complexity, the Gd rods are positioned asymmetrically, with the four rods shifted upward, as shown in Figure 7. An equivalent, symmetrical array would contain six rods, which are conservatively modeled. These are modeled as a total of fifteen features. Each feature is intended to represent the weighted combination of the following features: eight guide tubes, one instrument tube (treated as a guide tube), and six Gd_2O_3 rods. More detail is provided on this modeling in the section discussing the G3 assembly below—Section 6.3.7.

[27] Taken from Table 4-3.

Since it is not feasible to develop an exact model for this assembly type in SAS2H, a range of approaches were considered, and the most conservative treatment was selected (i.e., the treatment that yields the most reactive results, when a cask full of the given assemblies is modeled). In determining the most conservative way to model Assembly type G3, the following five model cases were considered.

1. Perform a run without modeling the Gd material at all. Again, model the GT's as the path-B feature.
2. Model the Gd fuel rod as the central path-B feature. Push the extra water and GT material to the outside of the model. This will be modeled as in the Takahama-3 example shown in NUREG/CR-ORNL/TM-2001/259 (page 51).
3. Model an empty guide tube as the central path-B feature and model Gd as an outer ring of material, preserving the area of the rods.
4. Model 6/15 of a Gd fuel rod and 9/15 of a guide tube as the central path-B feature. Model 15 of these "features" (to preserve the 8 GT, 1 instrument tube, and 6 Gd rod number).
5. Smear the Gd throughout all fuel. Model all fuel rods, including those that include the Gd material. Model the empty guide tubes as the path-B feature.

SAS2H models are prepared based on each of these approaches. In each case, the resulting spent fuel isotopic concentrations are then extracted with SASQUASH Version 1.0 and input to a corresponding MCNP run, otherwise unchanged except for titles and the k_{eff} starting guess. The SCALE and SASQUASH runs are shown in the computer run table in Section 8.1. These models are evaluated in MCNP runs assg31, assg32, assg33, assg34, and assg35 respectively. The results for these cases are presented in Table 6-2.

Table 6-2 Gd_2O_3 Scoping Cases

Case Name & Description	k_{eff}
assg31 – Case 1	0.916
assg32 – Case 2	0.917
assg33 – Case 3	0.918
assg34 – Case 4	0.919
assg35 – Case 5	0.917

The hybrid approach, case 4 above, is found to be the most conservative. This approach is used for G3 and H3 assemblies in the production work. The approach is further described in the G3 and H3 sections, Section 6.3.7 and Section 6.3.10 below.

6.2.5 Evaluation and Treatment of Effects of Stainless Steel Dummy Rods

Three of the fuel types include dummy rods made of stainless steel. These are types L2S and L3S (each containing fourteen SS rods) and H1S (containing 56 SS rods). A fourth assembly type, L1S, is described in the Reference 3.2.1 figures, but no assemblies of this type are included in the eighteen MSBs being evaluated.

The effects of stainless steel material around the outside of a SAS2H model are evaluated. This approach is particularly appropriate since, in all cases, the stainless steel rods are located at the outside of the fuel assembly—or along a single, extreme side in the case of the H1S assembly. All three cases model five cycles of operation; in the cases explicitly modeling stainless steel, the SS material is included only in the final two cycles (i.e., the cycles where the inserted SS rods were present). Three different cases were considered.

1. Case with no stainless steel modeled. Stainless steel rods are simply treated as fuel rods.
2. Case modeling the equivalent of 14 stainless steel rods. The number of fuel rods is decreased, and the outermost ring of the path-B model is modified to include both the stainless steel material and the zircaloy material (corresponding to the guide bars and the stainless steel rods).
3. Case modeling the equivalent of 56 stainless steel rods. Modeled in the same way as Case 2, but adjusted for the higher number of SS rods.

Each of these cases is based on assembly type L3S. In each case, the resulting spent fuel isotopic concentrations are then input to a corresponding MCNP run, otherwise unchanged except for titles and the k_{eff} starting guess. The SCALE runs are shown in the computer run table in Section 8.1. L01a0101 is the case name for the model treating the SS rods as UO_2. L01a0201 is the name for the 14-SS rod case. And L01a0301 is the case name for the model with 56 SS rods. These are evaluated in MCNP runs assyLS1, assyLS2, and assyLS3, respectively. The results for these cases are presented in Table 6-3.

Table 6-3 Stainless Steel Rod Scoping Cases

Case Name & Description	k_{eff}
L01a0101 – SS treated as UO2	0.898
L01a0201 – 14 SS rods modeled	0.896
L01a0301 – 56 SS rods modeled	0.891

The runs demonstrate that the effect of modeling stainless steel rods (in various numbers) as an outer ring around the path-B model is to reduce k_{eff} (this holds for 14 rods as well as for a smaller number). Therefore it is justifiable and appropriate to ignore the stainless steel rods in constructing our SASIGEN and SAS2H models.

In most or all cases, these dummy rods were installed after a number of initial cycles (typically 3) of operation for the given assembly. However, it is unnecessary to make use of the *mxrepeats=0*

command in SAS2H, since the conservative approach of continuing to model the rods as UO_2 fuel is used.

6.2.6 Path-B Model Results

Using the methodologies described in Sections 5.2, 5.3, 6.1, and 6.2, the SAS2H path-B models are determined for each of the Palisades assembly types described in Table 4-6 and in Figure 1 through Figure 21. The resulting path-B models are described in Table 6-5.

The radial dimensions of the central features (e.g., absorber rods, guide tubes, etc..) are generally taken directly from Table 4-6. The outer radii of the central feature's unit cell water and the material "500" zone are calculated as described in Section 5.2, based upon the number of modeled features (shown for each assembly type in Table 6-5), and the rod pitch and number of fuel rods data given in Table 4-6. The outer radii of the solid Zircaloy-4 guide bar zone (present in all assembly types) are calculated as discussed in Section 6.2.1 and are taken directly from Table 6-4. Finally, the radius of the outer water region is determined (based on the generic assembly pitch of 21.552 cm and the number of modeled features) such that the overall area of the assembly, per modeled feature (including the water between assemblies), is preserved.

As discussed in Section 6.1 and illustrated in Figure 23, the SASIGEN code creates eight path-B model zones in all cases. In cases where all eight zones are not needed, multiple adjacent zones of the same material are defined. In many cases, zones of infinitesimal (0.001 cm) thickness are also employed. Examination of Table 6-5 shows that this is done for many assembly types, such as assemblies that do not have poison rods inserted into guide tubes, for example, where multiple water zones are defined inside the guide tubes. In such cases, many of the radial dimensions are not relevant, and are therefore chosen arbitrarily. As discussed in Section 6.1, the SASIGEN code automatically sets such radii to be 0.001 cm less than the meaningful radius that lies just outboard.

As discussed in Section 5.4.1, the top two axial segments of a small number of assemblies have seen exposure to inserted control blades. Modeling these assembly zones involves an expanded, 10-zone path-B model. These analyses are discussed in detail in Section 6.7. For these assemblies, the inner seven zones of the path-B models shown in Table 6-5 (out to the outer edge of the guide bar Zircaloy-4 zone) remain the same. The outer water zone is replaced by three zones containing water, homogenized control blade material, and water, as is discussed in Section 6.7. Note that this change in the path-B model is only made for the top two axial zones of the affected assemblies. The path-B models for the bottom 16 axial zones remain as described in Table 6-5.

6.3 Model Descriptions of Specific Assemblies

The following notes are arranged in terms of the individual fuel assembly types. The physical assembly types are described and presented in Section 4.1. Figures are provided for all fuel types in Section 4 (Figure 1 through Figure 21).

The SASIGEN input model for each fuel types is presented in Section 6.4. The steps taken in customizing these types for use in modeling specific assemblies in a given cask are detailed in Section 6.5. The detailed numerical inputs for use in each of the fuel types are derived and presented in Table 6-1 and Table 6-4 (themselves taken from Excel spreadsheet Palisades_fuelinputs.xls, included on the archival media for this calculation) in addition to the main assembly sub-type numerical and dimensional descriptions provided in Table 4-6.

6.3.1 Fuel Type A1

Four features are modeled—the four B_4C rods with a boron concentration of 1.7 wt-%. CE dimensions (as opposed to Exxon) are used for the guide bar effective radius. Instrument tube water is automatically treated in SASIGEN by inclusion in the outermost path-B ring. This fuel type includes no guide tubes.

6.3.2 Fuel Type D1 (also called “EF”)

These assemblies have no difficult features other than a single instrument tube. But note that the guide bars are sized as the larger CE type (0.5953 cm).

6.3.3 Fuel Type E1

Includes 8 B_4C Rods. These rods are not surrounded by guide tubes. This fuel type has a B_4C fraction of 7.7%.

6.3.4 Fuel Type F1 (also called “XF”)

There are no complexities associated with this fuel assembly type. The assembly’s only feature is a single instrument tube. This tube is treated as the path-B model.

6.3.5 Fuel Type G1

These assemblies have guide tubes and mixed enrichments but can be easily modeled with SASIGEN. The plugging inserts are neglected in these assemblies, since they are situated only at the very top of an assembly.

6.3.6 Fuel Type G2

These assemblies have guide tubes in which B_4C rods are loaded. Since there are not enough rings in SASIGEN to permit the modeling of a gap between the B_4C rod and the clad, a reduced-density zircaloy is modeled in the combined clad/gap space. The VF to be used is found from the following equation to be 0.7407. This value applies to both the G2 and the H2 assembly types.

$$VF = \frac{R_{clad}^2 - R_{gap}^2}{R_{clad}^2 - R_{pellet}^2}$$

6.3.7 Fuel Type G3

These assemblies have guide tubes and also include four fuel rods with Gd_2O_3. These features are combined into a total of 15 composite "features," as discussed and justified in Section 6.2.4. Each has the equivalent of 6/15 of the fuel/Gd_2O_3 mixture of a single rod. An inner radius (R_1) of 0.282 cm is determined to represent this. The guide tube dimensions are used to model the clad around this hybrid (reduced area) absorber material, since this feature is more prevalent than the absorber rod cladding. The guide tubes surrounding the rods are kept at their actual thickness and can be regarded as representing either a guide tube or the clad of a rod.

6.3.8 Fuel Type H1 / H1S

Assembly Type H1 is based on Assembly Type G1.

The assembly numbers that have the type H1S are H01, H03, H31, H38, H39, H59, and H65.

1. MSB 15 includes only H65. This assembly was reconstituted, with the addition of 56 fresh stainless steel rods.
2. Following reconstitution, the assembly saw a very small additional burnup, to bring it from 34,143 MWD/MTU to 37,625 MWD/MTU.
3. Two separate calculations will be done for these assemblies:
    a. One of the first three cycles of operation: this will be used to model the fuel removed from the assembly.
    b. A second calculation of all four cycles of operation.
    c. The two calculations will be based on the following:
        i. 3 cycles – 208 rods – 0.388907 MTU initial loading
        ii. 4 cycles – 208 rods – 0.388907 MTU initial loading
    d. The second set will be used as the main data, and stored along with the rest of the MSB 15 data. The first set will be saved in a separate directory from the rest of the MSB 15 data, *extra15*.

6.3.9 Fuel Type H2

Nearly identical to I3 assemblies. Only guide tube dimensions are different. Since there are not enough rings in SASIGEN to permit the modeling of a gap between the B_4C rod and the clad, a reduced-density zircaloy is modeled in the combined clad/gap space. The VF to be used is found from the following equation to be 0.7407. This value applies to both the G2 and the H2 assembly type.

$$VF = \frac{R_{clad}^2 - R_{gap}^2}{R_{clad}^2 - R_{pellet}^2}$$

6.3.10 Fuel Type H3

Similar to G3 assemblies. The guide tube dimensions and Gd concentration are different. There are 8 Gd_2O_3 rods present in each of these assemblies.

The treatment of the H3 assemblies is based on the method described for G3 assemblies, above. These have eight guide tubes and also include eight fuel rods with Gd_2O_3.

a. These features are combined into a total of 17 composite "features"—including the instrument tube. Each has the equivalent of 8/17 of the fuel/Gd_2O_3 mixture of a single rod. An inner radius (R_1) is determined to represent this from the following, taken from the expressions for the actual and effective fuel pellet radius.

$$R_{eff} = \sqrt{R_{pellet}^2 \cdot 8/17}$$

b. The fuel pellet diameter for type H fuel is 0.8890 cm, and the numerical value for the effective pin radius is thus 0.305 cm. The guide tubes surround this rod and are kept at their actual thickness (to represent a guide tube or the clad of a rod).

6.3.11 Fuel Type I1 / I2 / J1

From a modeling standpoint, I1 and I2 are identical in form to G1. J1 is comparable to the I1 model; only the guide tube thickness (and thus IR) is different.

6.3.12 Fuel Type I3

Based on G2 assembly model. Note that fuel pellet, clad, and guide tube dimensions are different. Since there are not enough rings in SASIGEN to permit the modeling of a gap between the B_4C rod and the clad, a reduced-density zircaloy is modeled in the combined clad/gap space. The VF to be used is found from the following equation to be 0.7496.

$$VF = \frac{R_{clad}^2 - R_{gap}^2}{R_{clad}^2 - R_{pellet}^2}$$

6.3.13 Fuel Type I4 / J2 / K2

Based on G3 model. New concentrations and dimensions. Note that in this case, guide tubes are not present. The path-B model "guide tube" is taken to be the fuel rod cladding. The IR and OR are thus taken to be, respectively, 0.9093/2=.4546 cm and 1.0592/2=.5296 cm. For the fuel, the pellet OR is taken from 0.8890/2=0.444 cm. The model is constructed with an extremely low-density He fill in the fuel-to-clad gap. It should also be noted that, due to its being hardwired to placing water (material 3) immediately inside the "guide tube", the SCALE input file includes a 0.001 cm layer of water immediately inside the fuel rod. This is judged to be insignificant.

J2 and K2 are comparable to the I4 model. No physical dimensions are different. J2 and K2 are themselves physically identical.

6.3.14 Fuel Type I1H

Fuel with changing inserts: Assembly Type I1 becomes Assembly Type I1H

1. Following the first 4 cycles of operation, hafnium rods are inserted into the formerly empty guide tubes.

2. The final two cycles of operation include these absorbers.

There are 15 total assemblies of this type: three in MSB 15, two in MSB 16, three in MSB 17, four in MSB 18, and three in MSB 19. The I1 models were modified to add hafnium material. Although these fuel types are constructed, they are not run directly; rather they are used as the basis for the additional lines to be included in the multiple path-B models described below.

1. Since there are not enough rings in SASIGEN to permit the modeling of a gap between the Hf rod and the clad, a reduced-density zircaloy is modeled in the combined clad/gap space. The VF to be used is found from the following equation to be 0.835.

$$VF = \frac{R_{clad}^2 - R_{gap}^2}{R_{clad}^2 - R_{pellet}^2}$$

2. The change that is required between the Hf model and the base case model is simply a change of Mring1 and Mring2, the materials in ring1 and ring2 of the SASIGEN model. A material of 3 is used for water in the I1 cycles and 4 and 5 are used for the Hf and reduced-density zirc material, respectively.

In modeling the I1H assemblies, it is necessary to make use of multiple path-B model descriptions in the 15x18=270 SAS models for these assemblies. Since this is a cycle-specific geometry change, it is necessary to use the command "MXREPEATS=0" in the SAS2H input file, at the top of the path-B model section. Path-B composition data is then entered for each library set of each cycle's data. These changes can be made fairly automatically, and a process for doing this is described in Section 6.7.1.

6.3.15 Fuel Type L1 / L1S

L1 is configured like the F1 and D1 (EF) assemblies, with no features save a single instrument tube. F1 is used as the basis, since both F1 and L1 make use of similarly-dimensioned Exxon fuel.

6.3.16 Fuel Type L2 / L2S

a. Type L2 becomes type L2S
    i. This happens upon the replacement of a number of fuel rods with stainless steel rods.
    ii. For L2S fuel, 14 rods are replaced in this way.
b. As discussed in Section 6.2.5 above, it is justifiable and appropriate to ignore the stainless steel rods in constructing the SASIGEN and SAS2H models. That is, the replaced rods continue to be modeled in the path-B model as fuel rods. This represents a conservative treatment.
c. The L2S assemblies will thus be modeled in two sets of runs. The first set will model the burnup associated with the entire assembly. This set of data represents the removed rods (on a per MTU basis) and will be saved in a separate directory from the rest of the MSB 15 data. e.g., *extra15*.
d. Next, the fuel rods that remain in the L2S assembly (i.e., N - 14 rods) are modeled.
    iii. The model continues to model the replaced pins as fuel.
    iv. This is saved as the main L2S data for the MSB.
    v. Note that this second portion has a slightly higher enrichment, due to the fact that only lower-enrichment edge and corner rods are replaced with the stainless steel rods.
        3. The reported enrichment for assembly 16 in MSB 15 is 3.20%. The values that would be calculated from the assembly figures are:

$$\frac{2.85\% \cdot 46 + 3.38\% \cdot 148 + 2.47\% \cdot 8}{202} = 3.22\%$$

$$\frac{4 \cdot 2.47\% + 2.85\% \cdot 56 + 3.38\% \cdot 148 + 2.47\% \cdot 8}{216} = 3.19\%$$

4. This difference is so slight that it will be ignored. Both versions (remaining rods and removed rods) will be modeled at the enrichment reported on the Fuel Data Sheets.

e. Thus, the only things that change between the two cases (main directory and cask_15_extra-rods directory) are the time and burnup; there are additional cycles modeled in the final set of files.

f. The model for this assembly is based on the L3S model below; only the Gd_2O_3 concentration need be changed.

6.3.17 Fuel Type L3 / L3S

a. These assemblies are treated in the same fashion as the L2S assembly discussed above.
b. Again, the removal of the 14 rods has a small enough change on the assemblies' enrichments that it will be ignored; the Fuel Assembly Data sheet enrichment is used for both sets of calculations.
c. The identical assemblies I4, J2, and K2 are used as the basis for constructing this model. Only the pellet ID changes from these models to the L2 model.
d. Reference 3.2.2 describes the burnup at the point where fuel rods are replaced with stainless steel rods. In the case of assembly L15, for example, this takes place after the third cycle of operation.

Table 6-4 Determination of Modeled Guide Bar Thicknesses (sheet 1 of 2)

Type Designation	5 - G1[1]	2 - D1[2]	5 - G2[3]	5 - G3	4 - F[4 5]
Rod pitch, cm	1.397	1.397	1.397	1.397	1.397
Number of fuel rods[6]	208	216	208	202[7]	216
Modeled features[8]	9	1	8	15	1
Effective assembly pitch, cm	21.552	21.552	21.552	21.552	21.552
Effective radius, in	0.2274	0.2344	0.2274	0.2274	0.2274
Effective radius[9], cm	0.5776	0.5953	0.5776	0.5776	0.5776
Guide bar "rod" OD, cm	1.1552	1.1906	1.1552	1.1552	1.1552
Area per guide bar, cm^2	1.0481	1.1133	1.0481	1.0481	1.0481
Area for all 8 guide bars, cm^2	8.3848	8.9066	8.3848	8.3848	8.3848
Area per modeled feature, cm^2	0.932	8.907	1.048	0.559	8.385
# of fuel rods + modeled features	217	217	216[10]	217	217
Overall area: fuel + features, cm^2	423.499	423.499	421.548	423.499	423.499
Area per modeled feature, cm^2	47.055	423.499	52.693	28.233	423.499
Outer radius, fuel model[11], cm	3.8702	11.6105	4.0955	2.9978	11.6105
Rbar[12], cm	3.9083	11.7320	4.1360	3.0274	11.7249

[1] These values also pertain to assembly types I1, I2, and J1.

[2] Also referred to as "EF."

[3] These values also pertain to assembly type E1.

[4] Also referred to as "XF."

[5] These values also pertain to assembly type L1.

[6] Taken from Table 4-6.

[7] This number is used for the *pathB_npins* SASIGEN input variable. This feature must be used when the features modeled are themselves fuel.

[8] The choice of number of modeled features is discussed for each assembly type in Section 6.3.

[9] Taken from Table 4-5.

[10] The instrument tube is not modeled as a specific feature in the path-B model. SASIGEN models the "extra" water in the outermost ring.

[11] Calculated as discussed in Section 5.2, based on the rod pitch, number of fuel rods, and number of modeled features.

[12] Rbar is found from $((Rodpitch^2 * N_{features+rods} + A_{guide\text{-}bar}/N_{modeled\_features})/\pi)^{1/2}$.

Table 6-4 Determination of Modeled Guide Bar Thicknesses (sheet 2 of 2)

Type Designation	1 - A1	6 - H1	7 - I3[13]	7 - I4[14]	6 - H3
Rod pitch, cm	1.397	1.397	1.397	1.397	1.397
Number of fuel rods[15]	212	208	208	208[16]	200
Modeled features[17]	4	9	8	8	17
Effective assembly pitch, cm	21.552	21.552	21.552	21.552	21.552
Effective radius, in	0.2344	0.2274	0.2274	0.2274	0.2274
Effective radius[18], cm	0.5953	0.5776	0.5776	0.5776	0.5776
Guide bar "rod" OD, cm	1.1906	1.1552	1.1552	1.1552	1.1552
Area per guide bar, cm^2	1.1133	1.0481	1.0481	1.0481	1.0481
Area for all 8 guide bars, cm^2	8.9066	8.3848	8.3848	8.3848	8.3848
Area per modeled feature, cm^2	2.227	0.932	1.048	1.048	0.493
# of fuel rods + modeled features	216[19]	217	216	216	217
Overall area: fuel + features, cm^2	421.548	423.499	421.548	421.548	423.499
Area per modeled feature, cm^2	105.387	47.055	52.693	52.693	24.912
Outer radius, fuel model[20], cm	5.7919	3.8702	4.0955	4.0955	2.8160
Rbar[21], cm	5.8527	3.9083	4.1360	4.1360	2.8437

[13] These values also pertain to assembly type H2.

[14] These values also pertain to assembly types I1h, J2, K2, L2, and L3.

[15] Taken from Table 4-6.

[16] This number is used for the *pathB_npins* SASIGEN input variable. This feature must be used when the features modeled are themselves fuel.

[17] The choice of number of modeled features is discussed for each assembly type in Section 6.3.

[18] Taken from Table 4-7.

[19] The instrument tube is not modeled as a specific feature in the path-B model. SASIGEN models the "extra" water in the outermost ring.

[20] Calculated as discussed in Section 5.2, based on the rod pitch, number of fuel rods, and number of modeled features.

[21] Rbar is found from $((Rodpitch^2 * N_{features+rods} + A_{guide\text{-}bar}/N_{modeled\_features})/\pi)^{1/2}$.

Table 6-5 SAS2H Path-B Model Descriptions (by assembly type)

Assy Type	# of Features		SAS2H Path-B Model Zone #							
			1	2	3	4	5	6	7	8
A1	4	Material	B_4C[1]	Void[2]	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR[3]	0.452	0.0.463	0.464	0.525	0.788	5.792	5.853	6.080
D1	1	Material	H_2O	H_2O	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR	0.462	0.463	0.464	0.530	0.788	11.611	11.732	12.159
E1	8	Material	B_4C[1]	Void[2]	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR	0.445	0.454	0.455	0.527	0.788	4.095	4.136	4.299
F1	1	Material	H_2O	H_2O	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR	0.455	0.456	0.457	0.527	0.788	11.611	11.725	12.159
G1	9	Material	H_2O	H_2O	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR	0.410	0.420	0.497	0.528	0.788	3.870	3.908	4.053
G2	8	Material	B_4C[1]	Zirc-4[4]	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR	0.340	0.422	0.497	0.528	0.788	4.095	4.136	4.299
G3	15[5]	Material	Gd_2O_3[1]	H_2O	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR	0.282[5]	0.496	0.497	0.528	0.788	2.998	3.027	3.140
H1	9	Material	H_2O	H_2O	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR	0.410	0.420	0.497	0.530	0.788	3.870	3.908	4.053
H2	8	Material	B_4C[1]	Zirc-4[4]	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR	0.340	0.422	0.497	0.530	0.788	4.095	4.136	4.299
H3	17[5]	Material	Gd_2O_3[1]	H_2O	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR	0.305[5]	0.496	0.497	0.530	0.788	2.816	2.844	2.949
I1,I2	9	Material	H_2O	H_2O	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR	0.410	0.420	0.497	0.530	0.788	3.870	3.908	4.053
I1h	8	Material	Hafnium[6]	Zirc-4[4,6]	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR	0.350	0.422	0.494	0.530	0.788	4.095	4.136	4.299
I3	8	Material	B_4C[1]	Zirc-4[4]	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR	0.340	0.422	0.497	0.530	0.788	4.095	4.136	4.299
J1,K1	9	Material	H_2O	H_2O	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR	0.410	0.420	0.497	0.530	0.788	3.870	3.908	4.053
I4[7]	8	Material	Gd_2O_3[1]	Void[2]	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR	0.444	0.454	0.455	0.530	0.788	4.095	4.136	4.299
L1[8]	1	Material	H_2O	H_2O	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR	0.453	0.454	0.455	0.530	0.788	11.611	11.725	12.159
L2,L3[8]	8	Material	Gd_2O_3[1]	Void[2]	H_2O	Zirc-4	H_2O	"500"	Zirc-4	H_2O
		Ring OR	0.445	0.454	0.455	0.530	0.788	4.095	4.136	4.299

[1] The B_4C lies within an Al_2O_3 inert material, at the wt% given in Table 4-6. The Gd_2O_3 absorber lies within UO_2 fuel material, at the Table 4-6 wt%.

[2] Actually modeled as helium at an infinitesimal density (1.0×10^{-20} g/cc).

[3] Ring outer radii are given in cm.

[4] Reduced density Zircaloy-4 (see Section 6.3 discussions).

[5] This feature radius is based on the "hybrid" path-B modeling approach discussed in Section 6.2.4. The calculation of the effective absorber radius and the treatment of the cladding for the hybrid features are discussed in Section 6.2.4, and in Sections 6.3.7 and 6.3.10 for the G3 and H3 assemblies.

[6] These zones are modeled as water for the first three cycles of I1h assembly irradiation (as the hafnium insert is absent).

[7] This path-B model also applies for J2 and K2 assemblies.

[8] The "S versions" of these assemblies (which contain inserted steel rods) employ the same SAS2H path-B models as their standard assembly equivalents, as discussed in Section 6.2.5.

6.4 Fuel Type SASIGEN Models

The SASIGEN model for each of the fuel types is provided in the following list. Once developed, a model is typically used for each occurrence of a given fuel assembly type. These are customized for the individual MSB and location through the steps outlined in the following section. Further details on the SASIGEN code and its input description can be found in References 3.2.18 and 3.2.20.

```
 1  1 1.650 1 0.4120 1.3970 0.9119 1.0503 0.9284 2 212   0 335.28 3   Type 1
21.552 4 .4642 .5251 2 4 0.4521 8 0.4632 3 1 2 5.853                  Type 1-A1
12/31/1971 08/12/1973          Cycle 1A
                                        11111  8815  820.0 522.  566.
09/30/1974 12/20/1975          Cycle 1B
                                        11111  9181  450.0 522.  566.
b4c  4 den=4.0100 0.017
al   4 den=4.0100 0.520
o    4 den=4.0100 0.463
he   8 den=1.0e-20 1
===== A1 Assembly =====
 1  1 2.740 2 0.4152 1.3970 0.9093 1.0605 0.9284 4 216   0 333.76 0   Type 2
21.552 1 .4642 .5302 2 3 100.0 3 100.0 3 1 2 11.732                   Type 2-D1
05/09/1976 11/07/1977          Cycle 2A
                                           0  8815  500.0 522.  566.
11/07/1977 01/06/1978          Cycle 2B
                                        8815  9181   50.0 536.  583.
04/20/1978 09/08/1979          Cycle 3
                                        9181 21245  400.0 536.  583.
05/27/1980 08/29/1981          Cycle 4
                                        21245 30261  400.0 536.  583.
===== D1 Assembly =====
 1  1 3.050 3 0.3858 1.3970 0.8903 1.0541 0.9093 4 208   0 334.77 3   Type 3
21.552 8 .4547 .5271 2 4 0.4451 8 0.4537 3 1 2 4.136                  Type 3-E1
05/09/1976 11/07/1977          Cycle 2A
                                           0 14897  500.0 522.  566.
11/07/1977 01/06/1978          Cycle 2B
                                        14897 15535   50.0 536.  583.
04/20/1978 09/08/1979          Cycle 3
                                        15535 26360  400.0 536.  583.
05/27/1980 08/29/1981          Cycle 4
                                        26360 35333  400.0 536.  583.
b4c  4 den=3.3074 0.077
al   4 den=3.3074 0.488
o    4 den=3.3074 0.435
he   8 den=1.0e-20 1
===== E1 Assembly =====
 1  1 1.510 4 0.4001 1.3970 0.8903 1.0541 0.9093 2 216   0 334.77 0   Type 4
21.552 1 .4572 .5271 2 3 100.0 3 100.0 3 1 2 11.7249                  Type 4-F1
05/09/1976 11/07/1977          Cycle 2A
                                           0 11651  500.0 522.  566.
11/07/1977 01/06/1978          Cycle 2B
                                        11651 12990   50.0 536.  583.
===== F1 Assembly =====
 1  1 3.000 5 0.3869 1.3970 0.8903 1.0541 0.9093 3 208   0 334.77 0   Type 5
21.552 9 .4966 .5283 2 3 0.410 3 0.420 3 0 2 3.908                    Type 5-G1
04/20/1978 09/08/1979          Cycle 3
                                        0  8176   400.0 536.  583.
05/27/1980 08/29/1981          Cycle 4
                                        8176      19468  400.0 536.  583.
12/31/1981 08/12/1983          Cycle 5
                                        19468     31414  430.0 536.  583.
===== G1 Assembly =====
 1  1 3.000 5 0.3869 1.3970 0.8903 1.0541 0.9093 3 208   0 334.77 3   Type 5
21.552 8 .4966 .5283 2 4 0.3404 5 0.4216 3 1 2 4.136                  Type 5-G2
04/20/1978 09/08/1979          Cycle 3
                                           0 13092 400.0 536.  583.
05/27/1980 08/29/1981          Cycle 4
                                        13092 23754 400.0 536.  583.
12/31/1981 08/12/1983          Cycle 5
                                        23754 34930 430.0 536.  583.
b4c  4 den=3.3634 0.047
al   4 den=3.3634 0.504
o    4 den=3.3634 0.449
arbmzirc 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
         40000 98.18 5 .7407
===== G2 Assembly =====
```

```
 1  1 3.000 5 0.387  1.3970 0.8903 1.0541 0.9093 3 208 202 334.77 3   Type 5
21.552 15 .4966 .5283 2 9 0.282 3 0.496 3 0 2 3.0274                  Type 5-G3
04/20/1978 09/08/1979          Cycle 3
                                          0 10464 400.0 536.  583.
05/27/1980 08/29/1981          Cycle 4
                                      10464 22791 400.0 536.  583.
12/31/1981 08/12/1983          Cycle 5
                                      22791 33997 430.0 536.  583.
uo2  9 den=10.0602 1 750
   92234 0.027 92235 3.000 92236 0.014 92238 96.960 end
arbm-gd2o3  10.0602 2 0 1 1 64000 2 8016 3  9 0.01  750 end
===== G3 Assembly =====
 1  1 3.260 6 0.3885 1.3970 0.8890 1.0592 0.9093 3 208   0 334.77 0   Type 6
21.552 9 .4966 .5296 2 3 0.410 3 0.420 3 0 2 3.908                    Type 6-H1
05/27/1980 08/29/1981          Cycle 4
                                          0 10824  400.0 536.  583.
12/31/1981 08/12/1983          Cycle 5
                                      10824 25247  430.0 536.  583.
07/31/1984 11/30/1985          Cycle 6
                                      25247 34932  450.0 537.  587.
===== H1 Assembly =====
 1  1 3.260 6 0.3885 1.3970 0.8890 1.0592 0.9093 4 208   0 334.77 0   Type 6
21.552 9 .4966 .5296 2 3 0.410 3 0.420 3 0 2 3.908                    Type 6-H1S
05/27/1980 08/29/1981          Cycle 4
                                          0 10824  400.0 536.  583.
12/31/1981 08/12/1983          Cycle 5
                                      10824 25247  430.0 536.  583.
07/31/1984 11/30/1985          Cycle 6
                                      25247 34932  450.0 537.  587.
11/28/1988 09/15/1990          Cycle 8
                                      21803 32723  420.0 539.  589.
===== H1S Assembly =====
 1  1 3.260 6 0.3890 1.3970 0.8890 1.0592 0.9093 3 208   0 334.77 3   Type 6
21.552 8 .4966 .5296 2 4 0.3404 5 0.4216 3 1 2 4.136                  Type 6-H2
05/27/1980 08/29/1981          Cycle 4
                                          0 13275  400.0 536.  583.
12/31/1981 08/12/1983          Cycle 5
                                      13275 26294  430.0 536.  583.
07/31/1984 11/30/1985          Cycle 6
                                      26294 35215  450.0 537.  587.
b4c  4 den=3.3634 0.047
al   4 den=3.3634 0.504
o    4 den=3.3634 0.449
arbmzirc 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
         40000 98.18 5 .7407
===== H2 Assembly =====
 1  1 3.230 6 0.3883 1.3970 0.8890 1.0592 0.9093 3 208 200 334.77 3   Type 6
21.552 17 .4966 .5296 2 9 0.305 3 0.496 3 0 2 2.8437                  Type 6-H3
05/27/1980 08/29/1981          Cycle 4
                                          0 12927  400.0 536.  583.
12/31/1981 08/12/1983          Cycle 5
                                      12927 26164  430.0 536.  583.
07/31/1984 11/30/1985          Cycle 6
                                      26164 35078  450.0 537.  587.
uo2  9 den=10.1355 1 750
   92234 0.029 92235 3.230 92236 0.015 92238 96.726   end
arbm-gd2o3  10.1355 2 0 1 1 64000 2 8016 3  9 0.04  750 end
===== H3 Assembly =====
 1  1 3.260 7 0.3898 1.3970 0.8890 1.0592 0.9093 4 208   0 334.77 0   Type 7
21.552 9 .4940 .5296 2 3 0.410 3 0.420 3 0 2 3.908                    Type 7-I1
12/31/1981 08/12/1983          Cycle 5
                                          0 11714  430.0 536.  583.
07/31/1984 11/30/1985          Cycle 6
                                      11714 23236  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                      23236 24624  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                      24624 34678  440.0 537.  587.
===== I1 Assembly (or I2) =====
 1  1 3.260 7 0.3898 1.3970 0.8890 1.0592 0.9093 4 208   0 334.77 0   Type 7
21.552 9 .4940 .5296 2 3 0.410 3 0.420 3 0 2 3.908                    Type 7-I2
```

```
12/31/1981 08/12/1983          Cycle 5
                                          0 11714  430.0 536.  583.
07/31/1984 11/30/1985          Cycle 6
                                      11714 23236  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                      23236 24624  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                      24624 34678  440.0 537.  587.
===== I2 Assembly (or I1) =====
 1  1 3.250 7 0.3893 1.3970 0.8890 1.0592 0.9093 4 208   0 334.77 3   Type 7
21.552 8 .4940 .5296 2 4 0.3404 5 0.4242 3 1 2 4.136                  Type 7-I3
12/31/1981 08/12/1983          Cycle 5
                                      23754 34930  430.0 536.  583.
07/31/1984 11/30/1985          Cycle 6
                                      21803 32723  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                      21803 32723  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                      21803 32723  440.0 537.  587.
b4c  4 den=3.3634 0.047
al   4 den=3.3634 0.504
o    4 den=3.3634 0.449
arbmzirc 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
         40000 98.18 5 .7496
===== I3 Assembly =====
 1  1 3.240 9 0.404  1.3970 0.8890 1.0592 0.9093 4 216 208 334.77 4   Type 9
21.552  8 .4546 .5296 2 9 0.444 8 0.454 3 0 2 4.136                   Type 9-I4
12/31/1981 08/12/1983          Cycle 5
                                          0 14629  430.0 536.  583.
07/31/1984 11/30/1985          Cycle 6
                                      14629 25056  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                      25056 26277  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                      26277 34751  440.0 537.  587.
he   8 den=1.0e-20 1 750 end
uo2  9 den=10.1355 1  750
   92234 0.029 92235 3.240 92236 0.015 92238 96.716   end
arbm-gd2o3  10.1355 2 0 1 1 64000 2 8016 3  9 0.04  750 end
===== I4 Assembly =====
 1  1 3.260 7 0.3893 1.3970 0.8890 1.0592 0.9093 6 208   0 334.77 3   Type 7
21.552 8 .4940 .5296 2 4 0.3505 5 0.4216 3 1 2 4.136                  Type 7-I1H
12/31/1981 08/12/1983          Cycle 5
                                      23754 34930  430.0 536.  583.
07/31/1984 11/30/1985          Cycle 6
                                      21803 32723  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                      21803 32723  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                      21803 32723  440.0 537.  587.
03/15/1991 02/06/1992          Cycle 9
                                      21803 32723  370.0 536.  581.
04/18/1992 06/04/1993          Cycle 10
                                      21803 32723  420.0 536.  581.
hf   4 den=13.31  1
arbmzirc 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
         40000 98.18 5 .835
===== I1H Assembly (with Hafnium) =====
 1  1 3.260 8 0.3879 1.3970 0.8890 1.0592 0.9093 4 208   0 334.77 0   Type 8
21.552 9 .4966 .5296 2 3 0.410 3 0.420 3 0 2 3.908                    Type 8-J1
07/31/1984 11/30/1985          Cycle 6
                                      21803 32723  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                      21803 32723  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                      21803 32723  440.0 537.  587.
11/28/1988 09/15/1990          Cycle 8
                                      21803 32723  420.0 539.  589.
===== J1 Assembly =====
 1  1 3.240 9 0.4006 1.3970 0.8890 1.0592 0.9093 4 216 208 334.77 4   Type 9
21.552  8 .4546 .5296 2 9 0.444 8 0.454 3 0 2 4.136                   Type 9-J2
```

```
07/31/1984 11/30/1985          Cycle 6
                                       14629 25056  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                       25056 26277  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                       26277 34751  440.0 537.  587.
11/28/1988 09/15/1990          Cycle 8
                                       21803 32723  420.0 539.  589.
he   8 den=1.0e-20 1 750 end
uo2  9 den=10.125  1 750
   92234 0.029 92235 3.240 92236 0.015 92238 96.716   end
arbm-gd2o3  10.125  2 0 1 1 64000 2 8016 3  9 0.06  750 end
===== J2 Assembly =====
 1  1 3.250 9 0.4037 1.3970 0.8890 1.0592 0.9093 4 216 208 334.77 4   Type 9
21.552  8 .4546 .5296 2 9 0.444 8 0.454 3 0 2 4.136                   Type 9-K2
03/03/1986 05/19/1986          Cycle 7A
                                       25056 26277  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                       26277 34751  440.0 537.  587.
11/28/1988 09/15/1990          Cycle 8
                                       21803 32723  420.0 539.  589.
03/15/1991 02/06/1992          Cycle 9
                                       21803 32723  370.0 536.  581.
he   8 den=1.0e-20 1 750 end
uo2  9 den=10.204  1 750
   92234 0.029 92235 3.250 92236 0.015 92238 96.706   end
arbm-gd2o3  10.204  2 0 1 1 64000 2 8016 3  9 0.06  750 end
===== K2 Assembly =====
 1  1 3.220 10 0.4015 1.3970 0.8903 1.0592 0.9093 3 216   0 334.77 0  Type 10
21.552 1 .4547 .5296 2 3 100.0 3 100.0 3 1 2 11.7249                  Type 10-L1
11/28/1988 09/15/1990          Cycle 8
                                       21803 32723  420.0 539.  589.
03/15/1991 02/06/1992          Cycle 9
                                       21803 32723  370.0 536.  581.
04/18/1992 06/04/1993          Cycle 10
                                       21803 32723  420.0 536.  581.
===== L1 Assembly =====
 1  1 3.200 10 0.4006 1.3970 0.8903 1.0592 0.9093 3 216 208 334.77 4  Type 10
21.552  8 .4546 .5296 2 9 0.445 8 0.454 3 0 2 4.136                   Type 10-L2
11/28/1988 09/15/1990          Cycle 8
                                       21803 32723  420.0 539.  589.
03/15/1991 02/06/1992          Cycle 9
                                       21803 32723  370.0 536.  581.
04/18/1992 06/04/1993          Cycle 10
                                       21803 32723  420.0 536.  581.
he   8 den=1.0e-20 1 750 end
uo2  9 den=10.178  1 750
   92234 0.028 92235 3.200 92236 0.015 92238 96.757     end
arbm-gd2o3  10.178  2 0 1 1 64000 2 8016 3  9 0.04  750 end
===== L2 Assembly =====
 1  1 3.200 10 0.4006 1.3970 0.8903 1.0592 0.9093 5 216 208 334.77 4 Type 10
21.552  8 .4546 .5296 2 9 0.445 8 0.454 3 0 2 4.136                  Type 10-L2S
11/28/1988 09/15/1990          Cycle 8
                                       21803 32723  420.0 539.  589.
03/15/1991 02/06/1992          Cycle 9
                                       21803 32723  370.0 536.  581.
04/18/1992 06/04/1993          Cycle 10
                                       21803 32723  420.0 536.  581.
11/08/1993 02/17/1994          Cycle 11A
                                       21803 32723  880.0 536.  581.
06/18/1994 05/22/1995          Cycle 11B
                                       21803 32723  406.0 536.  581.
he   8 den=1.0e-20 1 750 end
uo2  9 den=10.096  1 750
   92234 0.028 92235 3.200 92236 0.015 92238 96.757   end
arbm-gd2o3  10.096  2 0 1 1 64000 2 8016 3  9 0.04  750 end
===== L2S Assembly =====
 1  1 3.140 10 0.4014 1.3970 0.8903 1.0592 0.9093 3 216 208 334.77 4  Type 10
21.552  8 .4546 .5296 2 9 0.445 8 0.454 3 0 2 4.136                   Type 10-L3
11/28/1988 09/15/1990          Cycle 8
                                       21803 32723  420.0 539.  589.
```

```
03/15/1991 02/06/1992          Cycle 9
                                       21803 32723  370.0 536.  581.
04/18/1992 06/04/1993          Cycle 10
                                       21803 32723  420.0 536.  581.
he   8 den=1.0e-20 1 750 end
uo2  9 den=10.178  1 750
   92234 0.028 92235 3.140 92236 0.014 92238 96.818   end
arbm-gd2o3  10.178  2 0 1 1 64000 2 8016 3  9 0.06  750 end
===== L3 Assembly =====
 1  1 3.140 10 0.4014 1.3970 0.8903 1.0592 0.9093 5 216 208 334.77 4 Type 10
21.552  8 .4546 .5296 2 9 0.445 8 0.454 3 0 2 4.136                  Type 10-L3S
11/28/1988 09/15/1990          Cycle 8
                                       21803 32723  420.0 539.  589.
03/15/1991 02/06/1992          Cycle 9
                                       21803 32723  370.0 536.  581.
04/18/1992 06/04/1993          Cycle 10
                                       21803 32723  420.0 536.  581.
11/08/1993 02/17/1994          Cycle 11A
                                       21803 32723  880.0 536.  581.
06/18/1994 05/22/1995          Cycle 11B
                                       21803 32723  406.0 536.  581.
he   8 den=1.0e-20 1 750 end
uo2  9 den=10.116  1 750
   92234 0.028 92235 3.140 92236 0.014 92238 96.818   end
arbm-gd2o3  10.116  2 0 1 1 64000 2 8016 3  9 0.06  750 end
===== L3S Assembly =====
```

6.5 Steps Taken in Preparing Runs

Once the fuel type models are obtained, as described above, a SASIGEN model is constructed for each of the MSBs.

The following steps are taken to prepare each SASIGEN run:

1. A workable SASIGEN input file is copied into a new cask's directory.
2. The correct assembly type data block (as shown in Section 6.4) is copied into the appropriate section of the SASIGEN input file. This file includes 24 such data blocks, corresponding to assemblies 1-24 in each MSB, as shown in the Attachment B tables[57].
3. The cask and assembly numbers are corrected[58].
4. The actual enrichment and initial heavy metal loading is entered for each assembly. (This is generally a small change, since the data for the correct assembly type is already close.)
5. The number of cycles and cycle dates and parameters are verified for each assembly and, if necessary, updated. (Note that for Palisades, the irradiation histories are virtually always the same for each assembly type, equating to those shown for each assembly type in Section 6.4.
6. The burnup ranges are copied over the existing burnup ranges. For burnups beyond a third operating cycle, the additional cycles of data are manually entered[59].
7. Run SASIGEN case. If desired, go back into the SASIGEN input file and revise the lines for the Gd_2O_3 assemblies; this can make the ^{234}U, ^{236}U values more accurate (be careful not to replace the material number inadvertently). Rerun SASIGEN.
8. For the assembly types that require cycle-specific modification (e.g., I1H), make the changes to the individual SAS2H input files in order to model the cycle-specific changes to the path-B model.

6.6 Modeling of Extra Fuel Rods

6.6.1 Fuel Rods Removed from Assemblies Loaded in Palisades MSBs

Following their final cycle of operation, the rods from several assemblies loaded into the Palisades MSBs were replaced with fuel rods taken from other assemblies. These assemblies were not subsequently placed back into the reactor and do not therefore have their operating histories affected by these switches. However, a full characterization of the fuel loaded in the MSBs does require the isotopic characterization of the spent fuel of these "extra" fuel rods.

---

[57] The Windows Wordpad editor is recommended for this step.

[58] The Unix "vi" editor or equivalent is recommended for this step.

[59] The Windows "ed" editor is recommended for column mode editing.

For donor assemblies which are themselves loaded into the MSB's, the extra rod SASIGEN input files are identical to their full-assembly models with only three exceptions:

- Only the donor assemblies from each MSB are modeled.
- Any cycles after the date where the donor rods were removed from the assembly being modeled are removed. In all cases the extra rods were removed after exactly three cycles of reactor operation—thus any additional cycles are removed from the SASIGEN input.
- The title card is changed to clarify that the run pertains to the removed extra rods only, for example, run P15ext03 is titled "Palisades Cask 15 – Extra Rods (fuel, pre-replacement)."

All runs for the extra donor fuel rods are listed in the table of computer runs in Section 8.1. Table 6-6 identifies the modeled fuel assemblies that become "donor" assemblies. The assembly numbers are provided for each cask containing donor assemblies.

Table 6-6 Donor Assemblies in MSBs Containing Donors

MSB Number	"Donor" Assemblies in Cask
15	11, 16, 20, 21
16	9, 10, 20
17	5, 8, 9, 11, 14, 20
18	5, 20, 21
19	5, 16

6.6.2 Fuel Rods Removed from Assemblies Not Loaded in Palisades MSBs

In addition to the rods associated with the assemblies listed in Table 6-6, it is also necessary to determine a fuel inventory for fuel rods taken five additional assemblies, as described in Reference 3.2.22. Unlike the other rods described in this section, these additional rods were not removed from assemblies that are loaded into the eighteen MSBs being analyzed in this calculation package. It is therefore necessary to construct an additional SASIGEN run to produce SAS2H files to analyze the inventory of these rods. Since the runs are again based on a single metric ton of initial uranium, it is immaterial whether the cases model the entire assemblies or merely rods from these assemblies.

The assemblies containing the additional rods are presented in Table 6-7. One of the assemblies, Assembly L02, is of Fuel Type L2 (Figure 18), while the remaining four are of Fuel Type L1 (Figure 16). All five assemblies were loaded in the Palisades reactor during plant cycles 8, 9, and 10. Table 6-7 provides the enrichment, fuel mass, and burnup data for each of the five assemblies. Initial enrichment values are provided in terms of initial ^{235}U wt-% (w/o). Initial UO_2 mass is provided in metric tons, and

burnup data is presented as the burnup (in MWD/MTU) at the end of each of the three operating cycles. All information is taken from Reference 3.2.22.

None of these assemblies require hand editing subsequent to the execution of the SASIGEN code. The assemblies do not include hafnium inserts, as do the I1H assemblies. They have not operated during the cycles with significant control blade insertion (Cycles 1A, 1B, or 2A). Finally, they do not include the reduced-density zircaloy material, as do the G2, H2, I3, and I1H assembly types. Thus the SASIGEN-produced SAS2H input files are appropriate for direct execution by the SAS2H code.

Table 6-7 Donor Assemblies in MSBs Containing Donors

Assembly Number	Init ^{235}U Enrichment (wt-%)	Init UO_2 Mass (MTU)	BU_{EOC} Cycle 8 (MWD/MTU)	BU_{EOC} Cycle 9 (MWD/MTU)	BU_{EOC} Cycle 10 (MWD/MTU)
L02	3.20	0.401	14,018	25,375	36,570
L33	3.23	0.402	14,197	25,893	37,709
L40	3.23	0.402	14,197	25,893	37,709
L47	3.23	0.402	14,197	25,893	37,709
L54	3.23	0.402	14,197	25,893	37,709

6.7 Modification of Automatically-Generated SAS2H Input Files

In several cases, it is necessary to make modifications to the SAS2H input files generated by SASIGEN. When this is necessary, lengths are taken to ensure two things. First, it is intended that the steps taken in making these changes are clearly described and reproducible. Second, inasmuch as it is possible, these steps are performed in a machine-assisted fashion, to lend the highest degree of confidence that the changes are made consistently and to save a significant amount of time—particularly in the event that these changes are made multiple times.

The specific cases are described below.

6.7.1 Treatment of I1H Assemblies

For the I1H assemblies, following the first 4 cycles of operation, hafnium rods were inserted into the formerly empty guide tubes. The assemblies were then loaded back into the reactor for two additional cycles of operation. Thus, the final two cycles of operation include these absorbers.

There are 15 total assemblies of this type: three in MSB 15, two in MSB 16, three in MSB 17, four in MSB 18, and three in MSB 19. The I1 models are used as the basis for the additional lines to be included in the multiple path-B models. These modifications to add hafnium material are described below.

1. Since there are not enough rings in SASIGEN to permit the modeling of a gap between the Hf rod and the clad, a reduced-density zircaloy is modeled in the combined clad/gap space. The VF to be used is found from the following equation to be 0.835.

$$VF = \frac{R_{clad}^2 - R_{gap}^2}{R_{clad}^2 - R_{pellet}^2}$$

2. The change that is required between the Hf model and the base case model is simply a change of Mring1 and Mring2, the materials in ring1 and ring2 of the SASIGEN model. A material of 3 is used for water in the I1 cycles and 4 and 5 are used for the Hf and reduced-density zirc material, respectively.

In modeling the I1H assemblies, it is necessary to make use of multiple path-B model descriptions in the 15x18=270 SAS models for these assemblies. This is accomplished by setting MXREPEATS=0 at the top of the path-B model section. Path-B composition data is then entered for each library set of each cycle's data. (Fortunately, these lines are all very similar.) These changes can be made fairly automatically in a text editor like the Unix 'vi' command, as in the following example.

```
:1,$ s/numztotal=8/numztotal=8, mxrepeats=0
/4 0.350  5 0.422  3 0.494  2 0.530  3 0.788 500  4.095  2  4.136  3  4.299
yy
:-2
17p
:-1
:.,+11:s/4 0.350  5/3 0.350  3/
:wq
:n
```

In this example, entered with the trailing hard return, the following steps are performed for an individual file:

- Through the entire file, occurrences of "numztotal=8" are replaced with "numztotal=8, mxrepeats=0" – that is, the mxrepeats=0 specification is inserted.
- The path-B specification line is found and copied
- Seventeen copies of this line are made.
- The first 12 versions of this line are modified so that the materials 4 and 5 are both replaced with material 3.
- The file is saved, and the next one is called up.

It should be noted that, in general form, the above steps are not editor-specific and could be used in nearly all modern editors.

6.7.2 Control Blade Models

As described in Reference 3.2.5, only a small number of fuel assemblies were adjacent to control blades during the first two full cycles of core operation—Cycles 1A, 1B, and 2A. Table 6-8 lists the affected casks and assemblies.

Table 6-8 Assemblies with Control Blade Models

Cask	Assembly	Cycle(s) Adjacent to Control Blade	Fuel Assembly Type	Assembly Cycles Including Ctl. Blades[60]
3	9	2A	F1	1/2
4	10	2A	F1	1/2
4	13	2A	D1	1/4
4	15	2A	F1	1/2
4	18	2A	D1	1/4
5	1	2A	F1	1/2
5	6	2A	F1	1/2
6	13	1A, 1B	A1	2/2
6	18	1A, 1B	A1	2/2
6	19	1A, 1B	A1	2/2
7	6	1A, 1B	A1	2/2
8	1	2A	F1	1/2
8	3	2A	D1	1/4
9	6	2A	F1	1/2
9	17	2A	D1	1/4
10	3	1A, 1B	A1	2/2
10	12	1A, 1B	A1	2/2
10	18	1A, 1B	A1	2/2
13	19	1A, 1B	A1	2/2

[60] Data in this column are shown as n/m (n of m), where n identifies the assembly cycle number(s) where the control blade is present and m identifies the total number of assembly cycle numbers. In all cases shown, the insert is present for the first cycle; in some (the identified A1 assemblies), the insert is present both for cycles 1 and 2, of a total of two cycles: this situation is denoted by the entry "2/2."

According to Reference 3.2.2, only group 4 has a history of control rods with significant insertion; the other blades were typically fully withdrawn. Over cycles 1A, 1B, and 2A, the group 4 control blades were typically 120 to 130" withdrawn. This corresponds to the upper 1.8 to 11.8" of active fuel height for the most common length of 131.8" (2 to 12" for Type A fuel with an height of 132" and 1.4 to 11.4" for Type EF fuel with an active height of 131.4"). From Reference 3.2.8 or 3.2.18, the eighteen axial segments being modeled are of equal size. This corresponds to the upper 8.95% of the assembly (9.09% or 8.68% for Type A or Type EF fuel). Thus, the control blades fall fully within the upper two axial zones, which represent the upper 1/9 (11.1%) of a given assembly. The control blades are therefore modeled in the upper two axial zones of the assemblies listed in Table 6-8. The control blades are modeled only during the cycle(s) for which a given assembly is located adjacent to a control blade: Cycle 1A, 1B, or 2A as appropriate. The affected cycles are also listed in Table 6-8.

The SAS2H input files for the axial zones containing control blade material are modified to the format shown in Figure 24; the model setup is described in Section 5.4.1. The new dimensions needed to make these modifications are developed in Table 6-9. The new dimensions needed are:

- the inner radius of the control blade ring (which is also the outer radius of the inner control blade channel)
- the outer radius of the control blade, including the stainless steel clad
- the outer radius of the water channel lying outside the control blade.

The water channel ring on each side of the control blade ring preserves the actual water thickness on each side of the control blade. This is obtained from the difference between the thickness of the wide channel dimension of .928 cm and the thickness of the control blade, including the 304 SS clad. Since the full thickness of the control blade is 0.5486 cm (the metric equivalent of .176" + 2 x .02" = 0.216"), this gives a total water thickness of 0.3794 cm. The thickness of the water channel inside and outside the control blade is thus 0.1897 cm.

The inner radius of the control blade ring is of course given by the outer radius of the inner water channel. The outer radius of the control blade ring is then sized to preserve the material associated with the "contributing area" of the control blade. The contributing area of the control blade is determined by dividing the full cruciform control blade area by the number of assemblies sharing that object. Since four assemblies surround a control blade, one fourth of the full cruciform blade's area is considered in constructing a path-B model.

As mentioned above, the new dimensions needed to make these modifications are developed in Table 6-9, which is taken from spreadsheet Palisades_fuelinputs.xls (shown in the appendix). The table presents the new radial dimensions for each of the three fuel types listed in Table 6-8.

The control blade ring for each of the fuel types contains a homogenous mixture of the clad and active control blade materials. The volume fraction of each of the two materials is found from the following.

$$VF_i = \frac{t_i}{t_i + t_j}$$

For clad and active control blade total thicknesses of .04" and .176", this gives volume fractions of 0.1852 and 0.8148, respectively. The total density for the ring is given by the weighted average of the two materials (themselves having densities of 7.94[61] and 10.5 g/cm^2). The weighted average is found to be 10.026 g/cm^2.

[61] The density for SS304 is taken from Reference 3.2.21.

Table 6-9 Additional Radial Dimensions for Control Blade Models

Type Designation	F1	D1	A1
Number of modeled features[62]	1	1	4
Effective radius, cm	0.5776	0.5953	0.5953
Guide bar "rod" OD, cm	1.1552	1.1906	1.1906
Area per guide bar, cm^2	1.0481	1.1133	1.1133
Area for all 8 guide bars, cm^2	8.3848	8.9066	8.9066
Area per modeled feature, cm^2	8.385	8.907	2.227
Control Blade Area w/ SS[63], in^2	5.245344	5.245344	5.245344
Control Blade Area w/ SS, cm^2	33.84086	33.84086	33.84086
Area of 1/4 Control Blade w/ SS, cm^2	8.460215	8.460215	8.460215
CB Area per modeled feature, cm^2	8.460215	8.460215	2.115054
# Fuel rods or modeled features	217	217	216
Area inside fuel model OR, cm^2	423.499	423.499	421.548
Area per modeled feature, cm^2	423.499	423.499	105.387
Outer radius, fuel model, cm	11.6105	11.6105	5.7919
R_{bar}, cm	11.7249	11.7320	5.8527
OR, control blade inner water channel[64], cm	11.9146	11.9217	6.0424
Area, outside inner water channel, cm^2	445.9722	446.5024	114.7026
OR, control blade and SS clad[65], cm	12.0271	12.0341	6.0979
R_{outer}[66], cm	12.2168	12.2238	6.2876

[62] Taken from Table 6-4.

[63] Calculated based on the control blade physical data given in Section 4.1.1.5.

[64] Equal to R_{bar} plus the inner assembly-to-blade water space of 0.1897 cm.

[65] Corresponds to a cylinder area equal to the inner water channel cylinder area (shown above) plus the control blade area per feature (also shown above).

[66] Equal to the control blade and SS clad OR plus the outer water gap thickness of 0.1897 cm.

6.7.3 Hand Edits of Reduced-Density Zircaloy Models

As discussed in Section 6.3, several assembly types involve the use of a reduced-density zircaloy material, which is necessitated by the fact that there are not enough rings in SASIGEN to permit the modeling of a gap between the Hf rod and the clad. As an alternative modeling method, the reduced-density zircaloy is modeled in the combined clad/gap space. The development of the Zirc relative density (or volume fraction) is described in Sections 6.3.6, 6.3.9, and 6.3.12 for the affected fuel assembly types: G2, H2, I3, and I1H.

Due to its having a sufficiently complex material definition, the SASIGEN-generated zircaloy material line for material 5 extends onto a second line. Without further editing, the formatting of this line leads to SAS2H run failures (specifically, when the code's *writemodtemp* feature is invoked, as is the case in these runs). To overcome this difficulty, a hand-edit is performed. The material definition is changed from this format:

```
arbmzirc 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40       569.6 end
         40000 98.18 5 .7407                                           569.6 end
```

to this:

```
arbmzirc 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
         40000 98.18 5 .7407                                           569.6 end
```

Although this is obviously a simple editing operation, it is facilitated through the use of a standardized set of editing operations. The following "vi" edit command sequence was used to delete the extraneous temperature and "end" label in the SAS2H input files for affected assembly types.

```
/50000 1.40
/
WWD
:w
:n
```

These editor commands simply find the character string '`50000 1.40`', move ahead two "words", delete the remainder of the line, write the file, and step to the next file in the editor sequence. The SAS2H input files are otherwise unchanged, with the exception of the I1H assemblies, whose additional edits are discussed elsewhere in this document.

7. CONCLUSIONS

7.1 Results

Isotopic results have been generated for each of the axial regions of each fuel assembly stored in a Palisades MSB. The results of these 7776 SAS2H runs are saved on individual CDs. Due to the large size of the files, there is at least one CD per cask, and in several cases, multiple CDs. The files are preserved in a standard compressed archive (zip) format, and an executable is included on each disk to facilitate the decompression.

As these files are in the native output format of the executed SCALE 4.4 modules, all nuclides produced by ORIGEN-S code are included. Final concentrations are expressed in terms of grams of a given nuclide per metric ton of initial uranium.

The envisaged method of making use of these results is to run the SASQASH code (Reference 3.2.19) for each of the MSBs. This would allow for the selection of the specific fission product and actinide nuclides of interest in performing a criticality analysis, properly accounting for burnup credit. The results of these SASQUASH runs would then be suitable for direct importing to the MCNP model for each MSB.

The contents of the folder for each MSB are consistent. In each case, 432 SAS2H input and 432 SAS2H output files are to be found, corresponding to the 18 axial locations in the 24 individual assemblies loaded in the MSB of interest. So for example, for the ninth axial region of the twelfth assembly in the first MSB, the input and output files are named s01a1209.inp and s01a1209.out, respectively.

As the file names are consistent within a single MSB's folder, the "auto-fill" feature of the SASQUASH code can be invoked. A user is thus required to enter only the first four characters (the "prefix") by way of SAS2H output file specification. In the above example, this prefix would be "s01a." This enables the automatic construction of all 432 files names. The specification and use of the auto-fill option of the SASQUASH code is discussed in detail in Reference 3.2.19.

The files in the directory for each MSB are themselves the result of multiple sets of SAS2H and multiple SASIGEN runs. The computer run table in Section 8.1 traces and clarifies the specific input file and run date for each ultimate SAS2H output file.

In addition to the SAS2H output files for each MSB, the CDs also include the extra fuel material associated with reconstituted fuel assemblies as discussed in Section 6.6. The specific assemblies and MSBs for which these extra SAS2H output files exist are detailed in Table 6-6. These runs are stored on a disc identified as "Additional Runs." Each extra assembly is located in a directory such as the following:

\VSC_Runs\Pal\Final\ExtraAA,

where AA is the two-digit MSB number. Within these directories, SAS2H output files are named as in the main results file example provided above, with an MSB, assembly number, and axial region identified—just as the s01a1209.inp example above.

In the case of these extra assemblies, a full set of 432 output files is not provided for any of the MSBs—since only the specific assemblies listed in Table 6-6 are modeled. Thus a user cannot make use of the auto-fill feature in the SASQUASH code. Nonetheless, the SASQUASH code can still be used to process the codes and will properly extract the results. These results (again expressed in terms of grams of the nuclide of interest per metric ton of initial uranium) can then be used in subsequent MCNP models to describe the fission product and actinide composition associated with the extra rods that have been placed in the reconstructed assemblies. Since the values are expressed per metric ton of initial uranium, they can be applied without difficulty to the number of rods placed into the reconstructed assembly. The reconstructed assemblies—and the assemblies from which the donor rods were taken—are described in Reference 3.2.4. The treatment of these reconstituted assemblies is to be described in detail in the criticality calculation package which is to be based on this current fuel depletion analysis.

In the case of several reconstituted assemblies, donor rods were taken from assemblies not loaded into the eighteen MSBs. The contents of these assemblies were modeled as described in Section 6.6.2; these results are also included in the CD collection.

The results of these calculations (which are in the form of SAS2H output files) are far too voluminous to present. The extraction of the spent fuel isotopic concentration results using the SASQUASH code (discussed earlier) will be performed as part of the subsequent Palisades criticality analyses. The resulting SASQUASH output, which will also form a section of the criticality code input files, will give the isotopic concentration results in a compact form. In addition to presenting the isotopic concentration results in this compact form, the SASQUASH code automatically gives detailed information for each block of concentration data, including the MSB, assembly, and axial zone number, along with the initial ^{235}U enrichment and final burnup level that the concentration data corresponds to. Thus, if one wishes to view the isotopic concentration results, for spot checking or comparison to independent calculations, one should reference the subsequent Palisades criticality analysis document.

7.2 Compliance With Requirements

No requirements were identified in Section 2.2. Section 2.1 described the consideration of a maximum reactivity system. The work in this calculation package supports this requirement.

7.3 Range of Validity

The results of these calculations pertain specifically to the assemblies currently loaded in the eighteen MSBs at the Palisades plant.

7.4 Summary of Conservatism

- In two cases, multiple ways of modeling a particular assembly or insert type have been considered. In such cases, the most conservative modeling approach has been used. The two cases where this was done are:
    - Assemblies containing both Gd_2O_3 rods and guide tubes are modeled by means of the hybrid modeling approach described in Section 6.2.4. As described in Section 6.2.4, this approach is found to be the most conservative treatment.
    - The stainless steel rods installed in place of fuel rods for certain fuel assemblies are neglected (i.e., modeled as fuel). As shown in Section 6.2.5, this represents a conservative treatment.
- The axial profiles built into the SASIGEN code are conservatively based on the axial profiles listed in Reference 3.2.8.
- Pure Al_2O_3 is loaded in sections of the poison rod that lie within the assembly active fuel zone, but above or below the axial bounds of the poison material; this material is conservatively modeled as the poison material in each axial region.
- For control blades that were present in the active fuel region of an assembly, the control blades actually ranged from 120" to 130" withdrawn, thus falling fully within the upper two axial zones, which represent the upper 1/9 (11.1%) of a given assembly. For control blades that were present in the active fuel region of an assembly, the SAS2H models conservatively model the control blade over the full length of the top two assembly zones.

7.5 Limitations or Special Instructions

It is recommended that the results of these assembly isotopic determinations be evaluated through the use of the SASQUASH computer code (References 3.2.17 and 3.2.19). The runs have been formatted, named, and configured with this approach in mind. Although a more manual process would not be incorrect, the efficiency gained through the use of SASQUASH will be extreme.

8. ELECTRONIC FILES

8.1 Computer Runs

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
SASIGEN Runs						
p01ssf01.inp (Cask 1 – used for all assemblies except 4 & 11) [assembly 18 subsequently edited]	7/8/05	SASIGEN	2	1.04	Windows XP	BFS0209
p01ssf02.inp (Cask 1 – correctly models all assemblies except those to be hand-edited)	7/15/05	SASIGEN	2	1.04	Windows XP	Crunch
p02ssf01.inp (Cask 2) [assemblies 3, 9, 16, 19, 20, and 22 files subsequently edited]	7/8/05	SASIGEN	2	1.04	Windows XP	BFS0209
p03ssf01.inp (Cask 3) – used for all assemblies except 6 & 7 [assemblies 4, 14, 17, and 21 files subsequently edited]	7/8/05	SASIGEN	2	1.04	Windows XP	BFS0209
p03ssf02.inp (Cask 3 – correctly models all assemblies except those to be hand-edited)	8/16/05	SASIGEN	2	1.04	Windows XP	BFS0209
p04ssf01.inp (Cask 4) – used for all assemblies except 16 [assemblies 4, 8, 14, 17, and 21 files subsequently edited]	7/8/05	SASIGEN	2	1.04	Windows XP	BFS0209

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
p04ssf02.inp (Cask 4 – correctly models all assemblies except those to be hand-edited)	8/16/05	SASIGEN	2	1.04	Windows XP	BFS0209
p05ssf01.inp (Cask 5 – used for all assemblies except 4, 5, 8, 15, 18, 19, 22, 23, & 24) [assemblies 11, 14, and 17 files subsequently edited]	7/8/05	SASIGEN	2	1.04	Windows XP	BFS0209
p05ssf03.inp (Cask 5 – correctly models all assemblies except those to be hand-edited)	8/16/05	SASIGEN	2	1.04	Windows XP	BFS0209
p06ssf01.inp (Cask 6 – used for all assemblies except 1, 2, 3, 6, 7, 12, 13, 18, 19, 22, 23, & 24) [assemblies 4, 5, and 8 files subsequently edited]	7/8/05	SASIGEN	2	1.04	Windows XP	BFS0209
p06ssf02.inp (Cask 6 – correctly models all assemblies except those to be hand-edited)	8/16/05	SASIGEN	2	1.04	Windows XP	BFS0209
p07ssf01.inp (Cask 7 – used for all assemblies except 1, 2, 3, 6, 7, 12, 13, 18, 19, 22, 23, & 24) [assemblies 10, 11, 14, 17, and 20 files subsequently edited]	7/8/05	SASIGEN	2	1.04	Windows XP	BFS0209
p07ssf02.inp (Cask 7 – correctly models all assemblies except those to be hand-edited)	8/16/05	SASIGEN	2	1.04	Windows XP	BFS0209

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
Po8ssi01.inp (all cask 8 assemblies)	3/31/05	SASIGEN	2	1.04	Windows XP	BFS0209
p09ssf01.inp (Cask 9)	7/8/05	SASIGEN	2	1.04	Windows XP	BFS0209
p09ssf03.inp (Cask 9) Used for assys 5 & 16, models all assemblies correctly	8/16/05	SASIGEN	2	1.04	Windows XP	BFS0209
P10ssf01.inp (Cask 10 – used for all assemblies except 1, 2, 3, 6, 7, 12, 13, 18, 19, 22, 23, & 24) [assemblies 5, 14, 16, 20, and 21 files subsequently edited]	7/11/05	SASIGEN	2	1.04	Windows XP	Crunch
P10ssf02.inp (Cask 10 – correctly models all assemblies except those to be hand-edited)	8/16/05	SASIGEN	2	1.04	Windows XP	BFS0209
P11ssf01.inp (Cask 11 – used for all assemblies except 4, 5, 8, 15, 18, 19, 22, 23, & 24) [assemblies 11 and 14 files subsequently edited]	7/11/05	SASIGEN	2	1.04	Windows XP	Crunch
P11ssf03.inp (Cask 11 – correctly models all assemblies except those to be hand-edited)	8/16/05	SASIGEN	2	1.04	Windows XP	BFS0209
P12ssf01.inp (Cask 12 – used for all assemblies except 4, 5, 8, 15, 18, 19, 22, 23, & 24) [assemblies 11, 14, and 16 files subsequently edited]	7/11/05	SASIGEN	2	1.04	Windows XP	Crunch

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
P12ssf03.inp (Cask 12 – correctly models all assemblies except those to be hand-edited)	7/15/05	SASIGEN	2	1.04	Windows XP	Crunch
P13ssf03.inp (Cask 13 – used for all assemblies except 15, 19, 22, 23, & 24) [assemblies 11 and 16 files subsequently edited]	8/12/05	SASIGEN	2	1.04	Windows XP	Crunch
P13ssf04.inp (Cask 13 – correctly models all assemblies except those to be hand-edited)	8/16/05	SASIGEN	2	1.04	Windows XP	BFS0209
P15ssf01.inp (Cask 15 – used for all assemblies except 2 & 12) [assembly 9, 10, and 15 files subsequently edited]	7/11/05	SASIGEN	2	1.04	Windows XP	Crunch
P15ssf02.inp (Cask 15, used for assembly 2)	7/15/05	SASIGEN	2	1.04	Windows XP	Crunch
P15ssf03.inp (Cask 15, used for assembly 12 – correctly models all assemblies except those to be hand-edited)	8/12/05	SASIGEN	2	1.04	Windows XP	Crunch
P16ssf01.inp (Cask 16 – used for all assemblies except 2 & 7) [assembly 15, 16, and 19 files subsequently edited]	7/11/05	SASIGEN	2	1.04	Windows XP	Crunch

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
P16ssf03.inp (Cask 16 – correctly models all assemblies except those to be hand-edited)	8/12/05	SASIGEN	2	1.04	Windows XP	Crunch
P17ssf01.inp (Cask 17 – used for all assemblies except 2) [assembly 10, 15, 16, and 19 files subsequently edited]	7/11/05	SASIGEN	2	1.04	Windows XP	Crunch
P17ssf02.inp (Cask 17 – correctly models all assemblies except those to be hand-edited)	7/15/05	SASIGEN	2	1.04	Windows XP	Crunch
P18ssf01.inp (Cask 18) [assembly 3, 9, 10, 15, 16, and 19 files subsequently edited]	7/11/05	SASIGEN	2	1.04	Windows XP	Crunch
P19ssf01.inp (Cask 19 – used for all assemblies except 7 & 23) [assembly 9, 10, 15, and 19 files subsequently edited]	7/11/05	SASIGEN	2	1.04	Windows XP	Crunch
P19ssf02.inp (Cask 19 – correctly models all assemblies except those to be hand-edited)	7/15/05	SASIGEN	2	1.04	Windows XP	Crunch
p15ext03.inp (models extra, removed rods only, assemblies 11, 16, 20, and 21)	8/19/05	SASIGEN	2	1.04	Windows XP	BFS0209
p16ext03.inp (models extra, removed rods only, assemblies 9, 10, and 20)	8/19/05	SASIGEN	2	1.04	Windows XP	BFS0209

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
p17ext02.inp (models extra, removed rods only, assemblies 5, 8, 9, 11, 14, and 20)	8/19/05	SASIGEN	2	1.04	Windows XP	BFS0209
p18ext01.inp (models extra, removed rods only, assemblies 5, 20, and 21)	8/19/05	SASIGEN	2	1.04	Windows XP	BFS0209
p19ext02.inp (models extra, removed rods only, assemblies 5 and 16)	8/19/05	SASIGEN	2	1.04	Windows XP	BFS0209
pnussi01.inp – models extra assemblies not contained in any of the 18 loaded casks (used for rod contributions)	1/4/06	SASIGEN	2	1.04	Windows XP	BFS0209
SCALE Runs (Using SAS2H Module of SCALE 4.4)						
All files listed in batch file runsas01.bat (All Cask 1 assemblies)	7/8/05 (alpha-numeric-ally through file s01a0806); 7/9/05 (files s01a0807 and greater)	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Files listed in runsas01_addit.bat (used for casks 4 & 11)	7/19/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Hand-edited files for Cask 1, Assembly 18 (s01a1801.inp through s01a1818.inp)	7/13/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
All files listed in batch file runsas02.bat (All Cask 2 assemblies)	7/9/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
Hand-edited files for Cask 2, Assemblies 3, 9, 16, 19, 20, and 22	7/13/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
All Cask 3 files listed in batch file runsas03.bat except assemblies 4, 6, 7, 14, 17 & 21)	9/2/05, s03a0101 - s03a0118; 7/9/05, all others	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Cask 3 files listed in runsas03_final.bat (assemblies 6 & 7)	8/16/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Hand-edited files for Cask 3, Assemblies 4, 14, 17, and 21	7/13/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
All Cask 4 files listed in batch file runsas04.bat except assemblies 4, 8, 14, 16, 17, and 21	7/9/05 (alpha-numeric-ally through file s04a1007); 7/10/05 (files s04a1008 and greater)	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Cask 4 files listed in runsas04_final.bat (assembly 16)	8/16/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Hand-edited files for Cask 4, Assemblies 4, 8, 14, 17, and 21	7/13/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
All Cask 5 files listed in batch file runsas05.bat except assemblies 4, 5, 8, 11, 14, 15, 17, 18, 19, 22, 23, & 24	7/10/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
Cask 5 files listed in runsas05_final.bat (assemblies 4, 5, 8, 15, 18, 19, 22, 23, & 24)	9/2/05, s05a1511, s05a1907; 8/16/05 all others	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Hand-edited files for Cask 5, Assemblies 11, 14, and 17	7/13/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
All Cask 6 files listed in batch file runsas06.bat except assemblies 1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 18, 19, 22, 23, & 24	7/10/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Cask 6 files listed in runsas06_final.bat (assemblies 1, 2, 3, 6, 7, 12, 13, 18, 19, 22, 23, & 24)	9/2/05, s06a0212; 8/16/05 all others	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Hand-edited files for Cask 6, Assemblies 4, 5, and 8	7/13/05 (s06a0401 through s06a0514); 7/14/05 (s06a0515 through s06a0818)	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
All Cask 7 files listed in batch file runsas07.bat except 1, 2, 3, 6, 7, 10, 11, 12, 13, 14, 17, 18, 19, 20, 22, 23, & 24)	7/10/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
Cask 7 files listed in runsas07_final.bat (assemblies 1, 2, 3, 6, 7, 12, 13, 18, 19, 22, 23, & 24)	8/16/05 (s07a0101 through s07a0703); 8/17/05 (s07a0704 through s07a2418), except s07a1306, s07a2210 - 9/2/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Hand-edited files for Cask 7, Assemblies 10, 11, 14, 17, and 20	7/14/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
All files listed in batch file runsas08.bat (All Cask 8 assemblies)	4/1/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
All Cask 9 files listed in batch file runsas09.bat except assemblies 5 & 16	7/10/05 (alpha-numeric-ally through file s09a0302); 7/11/05 (files s09a0303 and greater)	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Cask 9 files listed in runsas09_final.bat (assemblies 5 & 16)	8/17/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
All Cask 10 files listed in batch file runsas10.bat except assemblies 1, 2, 3, 5, 6, 7, 12, 13, 14, 16, 18, 19, 20, 21, 22, 23, & 24	7/11/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
Cask 10 files listed in runsas10_final.bat (assemblies 1, 2, 3, 6, 7, 12, 13, 18, 19, 22, 23, & 24)	9/2/05, s101807, s101906; 8/17/05 all others	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Hand-edited files for Cask 10, Assemblies 5, 14, 16, 20, and 21	7/14/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
All Cask 11 files listed in batch file runsas11.bat except assemblies 4, 5, 8, 11, 14, 15, 18, 19, 22, 23, & 24	7/11/05 (alpha-numeric-ally through file s11a1302); 7/12/05 (files s11a1303 and greater); except s111511, s112311, 9/2/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Cask 11 files listed in runsas11_final.bat (assemblies 4, 5, 8, 15, 18, 19, 22, 23, & 24)	8/17/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Hand-edited files for Cask 11, Assemblies 11 and 14	7/14/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
All Cask 12 files listed in batch file runsas12.bat except assemblies 4, 5, 8, 11, 14, 15, 16, 18, 19, 22, 23, & 24	7/12/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Cask 12 files listed in runsas12_final.bat (assemblies 4, 5, 8, 15, 18, 19, 22, 23, & 24)	8/17/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
Hand-edited files for Cask 12, Assemblies 11, 14, and 16	7/14/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
All Cask 13 files listed in batch file runsas13.bat except assemblies 15, 19, 22, 23, & 24 (Includes hand-edited files for assemblies 11 and 16)	8/12/05 (alpha-numeric-ally through file s13a1413); 8/13/05 (files s13a1414 and greater)	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Cask 13 files listed in runsas13_final.bat (assemblies 15, 19, 22, 23, & 24)	8/17/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
All Cask 15 assemblies, except assemblies 2 & 12 and hand-edited files	7/13/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Assembly 2 files listed in runsas15_addit.bat (used for cask 15 J2 assembly #2)	7/16/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Hand-edited files for Cask 15, Assemblies 9, 10, and 15	7/14/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Files listed in runsas15_assy12.bat (used for cask 15 J2 assembly #12)	8/13/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
All files listed in batch file runsas16.bat (All Cask 16 assemblies)	7/13/05 (alpha-numeric-ally through file s16a1412); 7/14/05 (files s16a1413 and greater)	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Files listed in runsas16_2-and-7.bat (used for cask 16 J2 assemblies #2 & 7)	8/13/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Hand-edited files for Cask 16, Assemblies 15, 16, and 19	7/14/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
All files listed in batch file runsas17.bat (All Cask 17 assemblies)	9/2/05, s170311, s170312; 7/14/05 all others	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Files listed in runsas17_addit.bat (used for cask 17 J2 assembly #2)	7/16/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Hand-edited files for Cask 17, Assemblies 10, 15, 16, and 19	7/14/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
All files listed in batch file runsas18.bat (All Cask 18 assemblies)	7/14/05 (alpha-numeric-ally through file s18a1211); 7/15/05 (files s18a1212 and greater)	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Hand-edited files for Cask 18, Assemblies 3, 9, 10, 15, 16, and 19	7/14/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
All files listed in batch file runsas19.bat (All Cask 19 assemblies up to s19a1318)	9/2/05, s19a0104 - s19a0109, s19a0116; 7/15/05 all others	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Files listed in runsas19_addit.bat (used for cask 19 J2 assemblies #7 & 23 as well as runs that bombed due to insufficient storage space)	9/2/05, s19a0901 - s19a1018, s19a1501 - s19a1518, s19a1901 - s19a1918; 7/16/05, all others	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Hand-edited files for Cask 19, Assemblies 9, 10, 15, and 19	7/14/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
All control blade runs, as identified in Table 6-8, listed in file multi_ctlbld.bat	9/2/05, files s04a1317, s04a1318, s04a1817, s04a1818, s08a0317, s08a0318, s09a1717, & s09a1718; 8/24/05, all other files	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Files listed in Extra15\runsas15.bat (assemblies 11, 16, 20, and 21) [Extra, removed rods for Cask 15 assemblies]	8/19/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Files listed in Extra16\runsas16.bat (assemblies 9, 10, and 20) [Extra, removed rods for Cask 16 assemblies]	8/19/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Files listed in Extra17\runsas17.bat (assemblies 5, 8, 9, 11, 14, and 20) [Extra, removed rods for Cask 17 assemblies]	8/22/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Files listed in Extra18\runsas18.bat (assemblies 5, 20, and 21) [Extra, removed rods for Cask 18 assemblies]	8/22/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
Files listed in Extra19\runsas16.bat (assemblies 5 and 16) [Extra, removed rods for Cask 19 assemblies]	8/22/05	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
Files listed in Extra_New\runsas01.bat – models extra assemblies not contained in any of the 18 loaded casks (used for rod contributions)	1/4/06	SCALE / SAS2H	2	4.4	Windows XP	BFS0209
L01a0101 – Assembly L3S case treating SS rods as UO_2 rods	1/19/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch
L01a0201 – Assembly L3S case modeling 14 SS rods at the outside of the path-B model	1/19/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch
L01a0301 – Assembly L3S case modeling 56 SS rods at the outside of the path-B model	1/19/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Scale runs for G3 scoping case 1, p01a0101 through p01a0118	1/14/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Scale runs for G3 scoping case 2, p01a0101 through p01a0118	1/17/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Scale runs for G3 scoping case 3, p01a0101 through p01a0118	1/14/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch
Scale runs for G3 scoping case 4, p01a0101 through p01a0118	1/14/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
Scale runs for G3 scoping case 5, p01a0101 through p01a0118	1/17/05	SCALE / SAS2H	2	4.4	Windows XP	Crunch
SASQUASH Runs						
SASQUASH runs for extracting G3 scoping results for case 1, sqg301.i	1/17/05	SASQUASH	2	1.0	Windows XP	Crunch
SASQUASH runs for extracting G3 scoping results for case 2, sqg302.i	1/17/05	SASQUASH	2	1.0	Windows XP	Crunch
SASQUASH runs for extracting G3 scoping results for case 3, sqg303.i	1/17/05	SASQUASH	2	1.0	Windows XP	Crunch
SASQUASH runs for extracting G3 scoping results for case 4, sqg304.i	1/17/05	SASQUASH	2	1.0	Windows XP	Crunch
SASQUASH runs for extracting G3 scoping results for case 5, sqg305.i	1/17/05	SASQUASH	2	1.0	Windows XP	Crunch
MCNP Runs						
MCNP run for G3 scoping case 1, assg31	1/17/05	MCNP	2	5	Windows XP	Crunch
MCNP run for G3 scoping case 2, assg32	1/17/05	MCNP	2	5	Windows XP	Crunch
MCNP run for G3 scoping case 3, assg33	1/17/05	MCNP	2	5	Windows XP	Crunch
MCNP run for G3 scoping case 4, assg34	1/17/05	MCNP	2	5	Windows XP	Crunch
MCNP run for G3 scoping case 5, assg35	1/17/05	MCNP	2	5	Windows XP	Crunch

Filename	File Date	Computer Code	Cat	Version	Platform	Machine
assyLS1 – "No Steel," Assembly L3S case treating SS rods as UO_2 rods	1/20/05	MCNP	2	5	Windows XP	Crunch
assyLS2 – "Actual Steel," Assembly L3S case modeling 14 SS rods at the outside of the path-B model	1/20/05	MCNP	2	5	Windows XP	Crunch
assyLS3 – "Maximum Steel," Assembly L3S case modeling 56 SS rods at the outside of the path-B model	1/20/05	MCNP	2	5	Windows XP	Crunch

8.2 Other Electronic Files

Filename	File Date	Description
Palisades_fuelinputs .xls	8/23/05	Excel spreadsheet – Documents the development of SASIGEN fuel type input parameters.
Palisades Fuel Data_Rev11-workingcopy.xls	4/8/05	Excel spreadsheet – Used to re-tabulate assembly burnup data

9. ATTACHMENT A - SAMPLE COMPUTER INPUT/OUTPUT

Run p19ssf02.inp, Example SASIGEN Run

```
(p19ssf02.inp) Palisades Cask 19
01/01/2015
0.25
19  1 3.250 8 0.3872 1.3970 0.8890 1.0592 0.9093 4 208   0 334.77 0   Type 8
21.552 9 .4966 .5296 2 3 0.410 3 0.420 3 0 2 3.908                     Type 8-J1
07/31/1984 11/30/1985          Cycle 6
                                        0 10116  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                    10116 11914  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                    11914 24017  440.0 537.  587.
11/28/1988 09/15/1990          Cycle 8
                                    24017 36133  420.0 539.  589.
===== J1 Assembly =====
19  2 2.740 2 0.4152 1.3970 0.9093 1.0605 0.9284 4 216   0 333.76 0   Type 2
21.552 1 .4642 .5302 2 3 100.0 3 100.0 3 1 2 11.732                    Type 2-D1
05/09/1976 11/07/1977          Cycle 2A
                                        0  7201  500.0 522.  566.
11/07/1977 01/06/1978          Cycle 2B
                                     7201  7518   50.0 536.  583.
04/20/1978 09/08/1979          Cycle 3
                                     7518 19637  400.0 536.  583.
05/27/1980 08/29/1981          Cycle 4
                                    19637 28825  400.0 536.  583.
===== D1 Assembly =====
19  3 3.260 6 0.3879 1.3970 0.8890 1.0592 0.9093 3 208   0 334.77 0   Type 6
21.552 9 .4966 .5296 2 3 0.410 3 0.420 3 0 2 3.908                     Type 6-H1
05/27/1980 08/29/1981          Cycle 4
                                        0 11212  400.0 536.  583.
12/31/1981 08/12/1983          Cycle 5
                                    11212 25794  430.0 536.  583.
07/31/1984 11/30/1985          Cycle 6
                                    25794 35205  450.0 537.  587.
===== H1 Assembly =====
19  4 3.240 9 0.4031 1.3970 0.8890 1.0592 0.9093 4 216 208 334.77 4   Type 9
21.552  8 .4546 .5296 2 9 0.444 8 0.454 3 0 2 4.136                    Type 9-K2
03/03/1986 05/19/1986          Cycle 7A
                                        0  1641  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                     1641 14209  440.0 537.  587.
11/28/1988 09/15/1990          Cycle 8
                                    14209 27754  420.0 539.  589.
03/15/1991 02/06/1992          Cycle 9
                                    27754 37607  370.0 536.  581.
he   8 den=1.0e-20 1 750 end
uo2  9 den=10.188  1 750
   92234 0.029 92235 3.240 92236 0.015 92238 96.716   end
arbm-gd2o3  10.188  2 0 1 1 64000 2 8016 3  9 0.06  750 end
===== K2 Assembly =====
19  5 3.140 10 0.4011 1.3970 0.8903 1.0592 0.9093 5 216 208 334.77 4 Type 10
21.552  8 .4546 .5296 2 9 0.445 8 0.454 3 0 2 4.136                   Type 10-L3S
11/28/1988 09/15/1990          Cycle 8
                                        0 14966  420.0 539.  589.
03/15/1991 02/06/1992          Cycle 9
                                    14966 26525  370.0 536.  581.
04/18/1992 06/04/1993          Cycle 10
                                    26525 30446  420.0 536.  581.
11/08/1993 02/17/1994          Cycle 11A
                                    30446 31063  880.0 536.  581.
06/18/1994 05/22/1995          Cycle 11B
                                    31063 33411  406.0 536.  581.
he   8 den=1.0e-20 1 750 end
```

```
uo2  9 den=10.108  1 750
   92234 0.028 92235 3.140 92236 0.014 92238 96.818   end
arbm-gd2o3  10.108  2 0 1 1 64000 2 8016 3  9 0.06  750 end
===== L3S Assembly =====
19  6 1.500 4 0.4032 1.3970 0.8903 1.0541 0.9093 2 216   0 334.77 0   Type 4
21.552 1 .4572 .5271 2 3 100.0 3 100.0 3 1 2 11.7249                  Type 4-F1
05/09/1976 11/07/1977          Cycle 2A
                                        0 11651  500.0 522.  566.
11/07/1977 01/06/1978          Cycle 2B
                                    11651 12990   50.0 536.  583.
===== F1 Assembly =====
19  7 3.240 9 0.4007 1.3970 0.8890 1.0592 0.9093 4 216 208 334.77 4   Type 9
21.552  8 .4546 .5296 2 9 0.444 8 0.454 3 0 2 4.136                   Type 9-J2
07/31/1984 11/30/1985          Cycle 6
                                        0 12278  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                    12278 13732  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                    13732 24273  440.0 537.  587.
11/28/1988 09/15/1990          Cycle 8
                                    24273 34943  420.0 539.  589.
he   8 den=1.0e-20 1 750 end
uo2  9 den=10.125  1 750
   92234 0.029 92235 3.240 92236 0.015 92238 96.716   end
arbm-gd2o3  10.125  2 0 1 1 64000 2 8016 3  9 0.06  750 end
===== J2 Assembly =====
19  8 3.220 10 0.4012 1.3970 0.8903 1.0592 0.9093 3 216   0 334.77 0  Type 10
21.552 1 .4547 .5296 2 3 100.0 3 100.0 3 1 2 11.7249                  Type 10-L1
11/28/1988 09/15/1990          Cycle 8
                                        0  8915  420.0 539.  589.
03/15/1991 02/06/1992          Cycle 9
                                     8915 21501  370.0 536.  581.
04/18/1992 06/04/1993          Cycle 10
                                    21501 34109  420.0 536.  581.
===== L1 Assembly =====
19  9 3.260 7 0.3893 1.3970 0.8890 1.0592 0.9093 6 208   0 334.77 3   Type 7
21.552 8 .4940 .5296 2 4 0.3505 5 0.4216 3 1 2 4.136                  Type 7-I1H
12/31/1981 08/12/1983          Cycle 5
                                        0 13218  430.0 536.  583.
07/31/1984 11/30/1985          Cycle 6
                                    13218 24715  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                    24715 26011  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                    26011 35116  440.0 537.  587.
03/15/1991 02/06/1992          Cycle 9
                                    35116 36690  370.0 536.  581.
04/18/1992 06/04/1993          Cycle 10
                                    36690 39556  420.0 536.  581.
hf   4 den=13.31  1
arbmzirc 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
         40000 98.18 5 .835
===== I1H Assembly (with Hafnium) =====
19 10 3.250 7 0.3902 1.3970 0.8890 1.0592 0.9093 6 208   0 334.77 3   Type 7
21.552 8 .4940 .5296 2 4 0.3505 5 0.4216 3 1 2 4.136                  Type 7-I1H
12/31/1981 08/12/1983          Cycle 5
                                        0 11278  430.0 536.  583.
07/31/1984 11/30/1985          Cycle 6
                                    11278 23630  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                    23630 24895  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                    24895 34342  440.0 537.  587.
03/15/1991 02/06/1992          Cycle 9
                                    34342 37561  370.0 536.  581.
04/18/1992 06/04/1993          Cycle 10
                                    37561 39364  420.0 536.  581.
hf   4 den=13.31  1
arbmzirc 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
         40000 98.18 5 .835
===== I1H Assembly (with Hafnium) =====
```

```
19 11 3.220 10 0.4017 1.3970 0.8903 1.0592 0.9093 3 216   0 334.77 0  Type 10
21.552 1 .4547 .5296 2 3 100.0 3 100.0 3 1 2 11.7249                   Type 10-L1
11/28/1988 09/15/1990          Cycle 8
                                          0  8915  420.0 539.  589.
03/15/1991 02/06/1992          Cycle 9
                                       8915 21501  370.0 536.  581.
04/18/1992 06/04/1993          Cycle 10
                                      21501 33662  420.0 536.  581.
===== L1 Assembly =====
19 12 3.250 8 0.3868 1.3970 0.8890 1.0592 0.9093 4 208   0 334.77 0   Type 8
21.552 9 .4966 .5296 2 3 0.410 3 0.420 3 0 2 3.908                     Type 8-J1
07/31/1984 11/30/1985          Cycle 6
                                          0 10483  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                      10483 12231  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                      12231 23998  440.0 537.  587.
11/28/1988 09/15/1990          Cycle 8
                                      23998 35932  420.0 539.  589.
===== J1 Assembly =====
19 13 3.260 8 0.3873 1.3970 0.8890 1.0592 0.9093 4 208   0 334.77 0   Type 8
21.552 9 .4966 .5296 2 3 0.410 3 0.420 3 0 2 3.908                     Type 8-J1
07/31/1984 11/30/1985          Cycle 6
                                          0 11053  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                      11053 12615  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                      12615 23920  440.0 537.  587.
11/28/1988 09/15/1990          Cycle 8
                                      23920 35984  420.0 539.  589.
===== J1 Assembly =====
19 14 3.220 10 0.4015 1.3970 0.8903 1.0592 0.9093 3 216   0 334.77 0  Type 10
21.552 1 .4547 .5296 2 3 100.0 3 100.0 3 1 2 11.7249                   Type 10-L1
11/28/1988 09/15/1990          Cycle 8
                                          0 14197  420.0 539.  589.
03/15/1991 02/06/1992          Cycle 9
                                      14197 25893  370.0 536.  581.
04/18/1992 06/04/1993          Cycle 10
                                      25893 37312  420.0 536.  581.
===== L1 Assembly =====
19 15 3.250 7 0.3898 1.3970 0.8890 1.0592 0.9093 6 208   0 334.77 3   Type 7
21.552 8 .4940 .5296 2 4 0.3505 5 0.4216 3 1 2 4.136                   Type 7-I1H
12/31/1981 08/12/1983          Cycle 5
                                          0 13218  430.0 536.  583.
07/31/1984 11/30/1985          Cycle 6
                                      13218 24715  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                      24715 26011  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                      26011 35116  440.0 537.  587.
03/15/1991 02/06/1992          Cycle 9
                                      35116 36690  370.0 536.  581.
04/18/1992 06/04/1993          Cycle 10
                                      36690 39273  420.0 536.  581.
hf   4 den=13.31  1
arbmzirc 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
         40000 98.18 5 .835
===== I1H Assembly (with Hafnium) =====
19 16 3.260 6 0.3896 1.3970 0.8890 1.0592 0.9093 4 208   0 334.77 0   Type 6
21.552 9 .4966 .5296 2 3 0.410 3 0.420 3 0 2 3.908                     Type 6-H1S
05/27/1980 08/29/1981          Cycle 4
                                          0  8126  400.0 536.  583.
12/31/1981 08/12/1983          Cycle 5
                                       8126 22652  430.0 536.  583.
07/31/1984 11/30/1985          Cycle 6
                                      22652 32974  450.0 537.  587.
11/28/1988 09/15/1990          Cycle 8
                                      32974 38584  420.0 539.  589.
===== H1S Assembly =====
19 17 3.220 10 0.4016 1.3970 0.8903 1.0592 0.9093 3 216   0 334.77 0  Type 10
21.552 1 .4547 .5296 2 3 100.0 3 100.0 3 1 2 11.7249                   Type 10-L1
```

```
11/28/1988 09/15/1990          Cycle 8
                                          0 10897  420.0 539.  589.
03/15/1991 02/06/1992          Cycle 9
                                      10897 22468  370.0 536.  581.
04/18/1992 06/04/1993          Cycle 10
                                      22468 34370  420.0 536.  581.
===== L1 Assembly =====
19 18 3.260 8 0.3879 1.3970 0.8890 1.0592 0.9093 4 208   0 334.77 0   Type 8
21.552 9 .4966 .5296 2 3 0.410 3 0.420 3 0 2 3.908                    Type 8-J1
07/31/1984 11/30/1985          Cycle 6
                                          0 10116  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                      10116 11914  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                      11914 24017  440.0 537.  587.
11/28/1988 09/15/1990          Cycle 8
                                      24017 36133  420.0 539.  589.
===== J1 Assembly =====
19 19 3.000 5 0.3863 1.3970 0.8903 1.0541 0.9093 3 208   0 334.77 5   Type 5
21.552 8 .4966 .5283 2 4 0.3404 5 0.4216 3 1 2 4.136                  Type 5-G2
04/20/1978 09/08/1979          Cycle 3
                                          0 13976 400.0 536.  583.
05/27/1980 08/29/1981          Cycle 4
                                      13976 24709 400.0 536.  583.
12/31/1981 08/12/1983          Cycle 5
                                      24709 35117 430.0 536.  583.
b4c  4 den=3.3634 0.047
al   4 den=3.3634 0.504
o    4 den=3.3634 0.449
arbmzirc 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
         40000 98.18 5 .7407
===== G2 Assembly =====
19 20 3.240 9 0.4038 1.3970 0.8890 1.0592 0.9093 4 216 208 334.77 4   Type 9
21.552  8 .4546 .5296 2 9 0.444 8 0.454 3 0 2 4.136                   Type 9-K2
03/03/1986 05/19/1986          Cycle 7A
                                          0  1641  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                       1641 14209  440.0 537.  587.
11/28/1988 09/15/1990          Cycle 8
                                      14209 27754  420.0 539.  589.
03/15/1991 02/06/1992          Cycle 9
                                      27754 37607  370.0 536.  581.
he   8 den=1.0e-20 1 750 end
uo2  9 den=10.206  1 750
   92234 0.029 92235 3.240 92236 0.015 92238 96.716   end
arbm-gd2o3  10.206  2 0 1 1 64000 2 8016 3  9 0.06  750 end
===== K2 Assembly =====
19 21 3.230 10 0.4017 1.3970 0.8903 1.0592 0.9093 3 216   0 334.77 0  Type 10
21.552 1 .4547 .5296 2 3 100.0 3 100.0 3 1 2 11.7249                  Type 10-L1
11/28/1988 09/15/1990          Cycle 8
                                          0 10897  420.0 539.  589.
03/15/1991 02/06/1992          Cycle 9
                                      10897 22468  370.0 536.  581.
04/18/1992 06/04/1993          Cycle 10
                                      22468 33959  420.0 536.  581.
===== L1 Assembly =====
19 22 3.230 7 0.3896 1.3970 0.8890 1.0592 0.9093 4 208   0 334.77 0   Type 7
21.552 9 .4940 .5296 2 3 0.410 3 0.420 3 0 2 3.908                    Type 7-I2
12/31/1981 08/12/1983          Cycle 5
                                          0 12768  430.0 536.  583.
07/31/1984 11/30/1985          Cycle 6
                                      12768 24199  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                      24199 25526  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                      25526 35141  440.0 537.  587.
===== I2 Assembly (or I1) =====
19 23 3.240 9 0.3989 1.3970 0.8890 1.0592 0.9093 4 216 208 334.77 4   Type 9
21.552  8 .4546 .5296 2 9 0.444 8 0.454 3 0 2 4.136                   Type 9-J2
07/31/1984 11/30/1985          Cycle 6
                                          0 12278  450.0 537.  587.
```

```
03/03/1986 05/19/1986          Cycle 7A
                                          12278 13732  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                          13732 24273  440.0 537.  587.
11/28/1988 09/15/1990          Cycle 8
                                          24273 34943  420.0 539.  589.
he   8 den=1.0e-20 1 750 end
uo2  9 den=10.125  1 750
   92234 0.029 92235 3.240 92236 0.015 92238 96.716   end
arbm-gd2o3  10.125  2 0 1 1 64000 2 8016 3  9 0.06  750 end
===== J2 Assembly =====
19 24 3.250 8 0.3874 1.3970 0.8890 1.0592 0.9093 4 208   0 334.77 0   Type 8
21.552 9 .4966 .5296 2 3 0.410 3 0.420 3 0 2 3.908                    Type 8-J1
07/31/1984 11/30/1985          Cycle 6
                                             0 10483  450.0 537.  587.
03/03/1986 05/19/1986          Cycle 7A
                                          10483 12231  930.0 537.  587.
04/03/1987 08/08/1988          Cycle 7B
                                          12231 23998  440.0 537.  587.
11/28/1988 09/15/1990          Cycle 8
                                          23998 35932  420.0 539.  589.
===== J1 Assembly =====
0
```

Run s19a0410.inp, Example SAS2H Run

```
=sas2     parm='halt12,skipshipdata'
1 MTU, Cask 19, Assy  4, 3.24%, 41.142 GWd/MTU, Ax Sec 10, 37.607 GWD/MTU Avg
' ===== K2 Assembly =====
'   Generated by sasigen version 1.04
' ------------------------------------------------------------
'
'   mixtures of fuel-pin-unit-cell:
'
44groupndf5    latticecell
uo2  1 den=10.188  1  763.8
   92234 0.029 92235 3.240 92236 0.015 92238 96.716   end
zr-94  1 0 1-20  763.8  end
mo-94  1 0 1-20  763.8  end
nb-95  1 0 1-20  763.8  end
mo-95  1 0 1-20  763.8  end
tc-99  1 0 1-20  763.8  end
rh-103 1 0 1-20  763.8  end
rh-105 1 0 1-20  763.8  end
ru-106 1 0 1-20  763.8  end
sn-126 1 0 1-20  763.8  end
xe-131 1 0 1-20  763.8  end
cs-134 1 0 1-20  763.8  end
cs-135 1 0 1-20  763.8  end
cs-137 1 0 1-20  763.8  end
pr-143 1 0 1-20  763.8  end
nd-143 1 0 1-20  763.8  end
ce-144 1 0 1-20  763.8  end
nd-144 1 0 1-20  763.8  end
nd-145 1 0 1-20  763.8  end
nd-146 1 0 1-20  763.8  end
nd-147 1 0 1-20  763.8  end
pm-147 1 0 1-20  763.8  end
sm-147 1 0 1-20  763.8  end
nd-148 1 0 1-20  763.8  end
pm-148 1 0 1-20  763.8  end
sm-148 1 0 1-20  763.8  end
pm-149 1 0 1-20  763.8  end
```

```
sm-149 1 0 1-20  763.8  end
nd-150 1 0 1-20  763.8  end
sm-150 1 0 1-20  763.8  end
sm-151 1 0 1-20  763.8  end
eu-151 1 0 1-20  763.8  end
sm-152 1 0 1-20  763.8  end
eu-153 1 0 1-20  763.8  end
eu-154 1 0 1-20  763.8  end
gd-154 1 0 1-20  763.8  end
eu-155 1 0 1-20  763.8  end
gd-155 1 0 1-20  763.8  end
gd-157 1 0 1-20  763.8  end
gd-158 1 0 1-20  763.8  end
gd-160 1 0 1-20  763.8  end
'  need the following to use the endf/b5 library
arbmzirc 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
         40000 98.18 2 1.0 617.5 end
h2o  3 den=0.7358  1  568.8 end
arbm-bormod  0.7358 1 1 0 0 5000 100 3 930.0E-6  568.8  end
he   8 den=1.0e-20 1 750 end
uo2  9 den=10.188  1 750
   92234 0.029 92235 3.240 92236 0.015 92238 96.716   end
arbm-gd2o3  10.188  2 0 1 1 64000 2 8016 3  9 0.06  750 end
'
'  930. ppm boron (wt) in moderator
' ------------------------------------------------------------
end comp
'
' ------------------------------------------------------------
'
'      fuel-pin-cell geometry:
'
squarepitch   1.3970  0.8890 1  3  1.0592  2  0.9093   0  end
'
' ------------------------------------------------------------
'
'    assembly and cycle parameters
'
npin/assm=216 fuelngth=830.49  ncycles= 4 nlib/cyc= 3
printlevel=5 lightel=9  inplevel=2 numztotal=8   end
 9 0.444  8 0.454  3 0.455  2 0.530  3 0.788 500  4.095  2  4.136  3  4.299
power=23.315 burn= 77 down=  319     end
power=27.889 burn=493 down=  112  bfrac=0.473 h2ofrac=1.000
tmpfuel= 802.0 tmpclad= 627.1 tmpmod= 568.8   end
power=22.589 burn=656 down=  181  bfrac=0.452 h2ofrac=0.997
tmpfuel= 758.8 tmpclad= 617.1 tmpmod= 569.9   end
power=32.863 burn=328 down= 8365  bfrac=0.398 h2ofrac=1.006
tmpfuel= 841.5 tmpclad= 635.4 tmpmod= 566.7   end
  o 119  cr  5.2  mn  0.29
  fe 11. co 0.066 ni  8.7
  zr 195 nb  0.63 sn  3.2
'
' ------------------------------------------------------------
'
end
```

10. ATTACHMENT B – EXCEL SPREADSHEETS

Attachments:

1. Assembly Parameters (Enrichment, Fuel Mass, Cycle IDs)	18 pages
2. Assembly Parameters (Cyclewise Burnups)	11 pages
	(29 pages total)

Assembly Parameters - Palisades Plant
Attachment to VSC-03.3605

MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
1	1	G01	5	3.00%	0.39	3	4	5				G3
1	2	G02	5	3.00%	0.39	3	4	5				G3
1	3	G03	5	3.00%	0.39	3	4	5				G3
1	4	G04	5	3.00%	0.39	3	4	5				G1
1	5	G05	5	3.00%	0.39	3	4	5				G3
1	6	G06	5	3.00%	0.39	3	4	5				G3
1	7	G07	5	3.00%	0.39	3	4	5				G3
1	8	G08	5	3.00%	0.39	3	4	5				G3
1	9	G09	5	3.00%	0.39	3	4	5				G1
1	10	G10	5	3.00%	0.39	3	4	5				G3
1	11	G11	5	3.00%	0.39	3	4	5				G1
1	12	G12	5	3.00%	0.39	3	4	5				G1
1	13	G13	5	3.00%	0.39	3	4	5				G1
1	14	G14	5	3.00%	0.39	3	4	5				G1
1	15	G15	5	3.00%	0.39	3	4	5				G1
1	16	G16	5	3.00%	0.39	3	4	5				G1
1	17	G17	5	3.00%	0.39	3	4	5				G1
1	18	G18	5	3.00%	0.39	3	4	5				G2
1	19	G20	5	3.00%	0.39	3	4	5				G1
1	20	G21	5	3.00%	0.39	3	4	5				G1
1	21	G22	5	3.00%	0.39	3	4	5				G1
1	22	G23	5	3.00%	0.39	3	4	5				G1
1	23	G24	5	3.00%	0.39	3	4	5				G1
1	24	G25	5	3.00%	0.39	3	4	5				G1

Assembly Parameters - Palisades Plant
Attachment to VSC-03.3605

MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
2	1	G27	5	3.00%	0.39	3	4	5				G1
2	2	G28	5	3.00%	0.39	3	4	5				G1
2	3	G29	5	3.00%	0.39	3	4	5				G2
2	4	G31	5	3.00%	0.39	3	4	5				G1
2	5	G32	5	3.00%	0.39	3	4	5				G1
2	6	G33	5	3.00%	0.39	3	4	5				G1
2	7	G34	5	3.00%	0.39	3	4	5				G1
2	8	G37	5	3.00%	0.39	3	4	5				G1
2	9	G38	5	3.00%	0.39	3	4	5				G2
2	10	G39	5	3.00%	0.39	3	4	5				G1
2	11	G40	5	3.00%	0.39	3	4	5				G1
2	12	G41	5	3.00%	0.39	3	4	5				G1
2	13	G43	5	3.00%	0.39	3	4	5				G1
2	14	G44	5	3.00%	0.39	3	4	5				G1
2	15	G45	5	3.00%	0.39	3	4	5				G1
2	16	G46	5	3.00%	0.39	3	4	5				G2
2	17	G48	5	3.00%	0.39	3	4	5				G1
2	18	G50	5	3.00%	0.39	3	4	5				G1
2	19	G53	5	3.00%	0.39	3	4	5				G2
2	20	G54	5	3.00%	0.39	3	4	5				G2
2	21	G57	5	3.00%	0.39	3	4	5				G1
2	22	G59	5	3.00%	0.39	3	4	5				G2
2	23	G60	5	3.00%	0.39	3	4	5				G1
2	24	G63	5	3.00%	0.39	3	4	5				G1

Assembly Parameters - Palisades Plant
Attachment to VSC-03.3605

MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
3	1	EF00	2	2.74%	0.42	2A	2B	3	4			D1
3	2	EF01	2	2.74%	0.42	2A	2B	3	4			D1
3	3	EF02	2	2.74%	0.42	2A	2B	3	4			D1
3	4	G26	5	3.00%	0.39	3	4	5				G2
3	5	XF02	4	1.51%	0.40	2A	2B					F1
3	6	D102	3	3.05%	0.39	2A	2B	3	4			E1
3	7	E14	3	3.05%	0.39	2A	2B	3	4			E1
3	8	G68	5	3.00%	0.39	3	4	5				G1
3	9	XF08	4	1.50%	0.40	2A	2B					F1
3	10	XF09	4	1.50%	0.40	2A	2B					F1
3	11	XF10	4	1.50%	0.40	2A	2B					F1
3	12	EF11	2	2.74%	0.42	2A	2B	3	4			D1
3	13	EF13	2	2.74%	0.42	2A	2B	3	4			D1
3	14	G47	5	3.00%	0.39	3	4	5				G2
3	15	XF15	4	1.50%	0.40	2A	2B					F1
3	16	XF16	4	1.51%	0.40	2A	2B					F1
3	17	G51	5	3.00%	0.39	3	4	5				G2
3	18	EF14	2	2.74%	0.42	2A	2B	3	4			D1
3	19	EF16	2	2.74%	0.42	2A	2B	3	4			D1
3	20	G55	5	3.00%	0.39	3	4	5				G2
3	21	G56	5	3.00%	0.39	3	4	5				G2
3	22	EF18	2	2.74%	0.42	2A	2B	3	4			D1
3	23	EF19	2	2.73%	0.42	2A	2B	3	4			D1
3	24	EF0H	2	2.74%	0.42	2A	2B	3	4			D1

Assembly Parameters - Palisades Plant
Attachment to VSC-03.3605

MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
4	1	EF0C	2	2.74%	0.42	2A	2B	3	4			D1
4	2	EF0X	2	2.74%	0.42	2A	2B	3	4			D1
4	3	EF0Y	2	2.75%	0.42	2A	2B	3	4			D1
4	4	G61	5	3.00%	0.39	3	4	5				G2
4	5	XF20	4	1.50%	0.40	2A	2B					F1
4	6	EF0Z	2	2.74%	0.42	2A	2B	3	4			D1
4	7	EF1G	2	2.74%	0.42	2A	2B	3	4			D1
4	8	G62	5	3.00%	0.39	3	4	5				G2
4	9	XF22	4	1.51%	0.40	2A	2B					F1
4	10	XF30	4	1.50%	0.40	2A	2B					F1
4	11	XF46	4	1.50%	0.40	2A	2B					F1
4	12	EF1H	2	2.74%	0.42	2A	2B	3	4			D1
4	13	EF1J	2	2.73%	0.41	2A	2B	3	4			D1
4	14	G65	5	3.00%	0.39	3	4	5				G1
4	15	XF51	4	1.50%	0.40	2A	2B					F1
4	16	E65	3	3.05%	0.39	2A	2B	3	4			E1
4	17	G66	5	3.00%	0.39	3	4	5				G2
4	18	EF1K	2	2.73%	0.42	2A	2B	3	4			D1
4	19	EF1R	2	2.74%	0.41	2A	2B	3	4			D1
4	20	G67	5	3.00%	0.39	3	4	5				G1
4	21	G30	5	3.00%	0.39	3	4	5				G2
4	22	EF06	2	2.74%	0.42	2A	2B	3	4			D1
4	23	EF10	2	2.74%	0.42	2A	2B	3	4			D1
4	24	XF53	4	1.51%	0.40	2A	2B					F1

Assembly Parameters - Palisades Plant
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MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
5	1	XF21	4	1.50%	0.40	2A	2B					F1
5	2	XF23	4	1.51%	0.40	2A	2B					F1
5	3	XF24	4	1.51%	0.40	2A	2B					F1
5	4	I01	9	3.24%	0.40	5	6	7A	7B			I4
5	5	I02	9	3.24%	0.40	5	6	7A	7B			I4
5	6	XF25	4	1.50%	0.40	2A	2B					F1
5	7	XF26	4	1.50%	0.40	2A	2B					F1
5	8	I03	9	3.24%	0.40	5	6	7A	7B			I4
5	9	XF27	4	1.50%	0.40	2A	2B					F1
5	10	XF28	4	1.51%	0.40	2A	2B					F1
5	11	I13	7	3.26%	0.39	5	6	7A	7B			I3
5	12	XF29	4	1.51%	0.40	2A	2B					F1
5	13	XF31	4	1.50%	0.40	2A	2B					F1
5	14	I14	7	3.26%	0.39	5	6	7A	7B			I3
5	15	A21	1	1.66%	0.41	1A	1B					A1
5	16	H57	6	3.26%	0.39	4	5	6				H1
5	17	I15	7	3.25%	0.39	5	6	7A	7B			I3
5	18	A23	1	1.65%	0.41	1A	1B					A1
5	19	A26	1	1.66%	0.41	1A	1B					A1
5	20	I29	7	3.26%	0.39	5	6	7A	7B			I1
5	21	I30	7	3.25%	0.39	5	6	7A	7B			I1
5	22	A28	1	1.66%	0.41	1A	1B					A1
5	23	A68	1	1.66%	0.41	1A	1B					A1
5	24	A39	1	1.65%	0.41	1A	1B					A1

Assembly Parameters - Palisades Plant
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MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
6	1	A33	1	1.65%	0.41	1A	1B					A1
6	2	A35	1	1.65%	0.41	1A	1B					A1
6	3	A36	1	1.65%	0.41	1A	1B					A1
6	4	H42	6	3.26%	0.39	4	5	6				H2
6	5	H43	6	3.26%	0.39	4	5	6				H2
6	6	A38	1	1.65%	0.41	1A	1B					A1
6	7	A42	1	1.65%	0.41	1A	1B					A1
6	8	H46	6	3.26%	0.39	4	5	6				H2
6	9	H48	6	3.26%	0.39	4	5	6				H1
6	10	H49	6	3.26%	0.39	4	5	6				H1
6	11	H53	6	3.26%	0.39	4	5	6				H1
6	12	A52	1	1.65%	0.41	1A	1B					A1
6	13	A54	1	1.65%	0.41	1A	1B					A1
6	14	H54	6	3.26%	0.39	4	5	6				H1
6	15	H56	6	3.26%	0.39	4	5	6				H1
6	16	H26	6	3.26%	0.39	4	5	6				H1
6	17	H64	6	3.23%	0.39	4	5	6				H3
6	18	A58	1	1.66%	0.41	1A	1B					A1
6	19	A59	1	1.65%	0.41	1A	1B					A1
6	20	H62	6	3.23%	0.39	4	5	6				H3
6	21	H63	6	3.23%	0.39	4	5	6				H3
6	22	A60	1	1.66%	0.41	1A	1B					A1
6	23	A61	1	1.66%	0.41	1A	1B					A1
6	24	A65	1	1.65%	0.41	1A	1B					A1

Assembly Parameters - Palisades Plant
Attachment to VSC-03.3605

MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
7	1	A01	1	1.66%	0.41	1A	1B					A1
7	2	A02	1	1.65%	0.41	1A	1B					A1
7	3	A03	1	1.65%	0.41	1A	1B					A1
7	4	H02	6	3.26%	0.39	4	5	6				H1
7	5	H08	6	3.26%	0.39	4	5	6				H1
7	6	A10	1	1.65%	0.41	1A	1B					A1
7	7	A14	1	1.66%	0.41	1A	1B					A1
7	8	H12	6	3.26%	0.39	4	5	6				H1
7	9	H17	6	3.26%	0.39	4	5	6				H1
7	10	H24	6	3.26%	0.39	4	5	6				H2
7	11	H23	6	3.26%	0.39	4	5	6				H2
7	12	A22	1	1.65%	0.41	1A	1B					A1
7	13	A25	1	1.65%	0.41	1A	1B					A1
7	14	H27	6	3.26%	0.39	4	5	6				H2
7	15	H14	6	3.26%	0.39	4	5	6				H1
7	16	H33	6	3.26%	0.39	4	5	6				H1
7	17	H34	6	3.26%	0.39	4	5	6				H2
7	18	A27	1	1.66%	0.41	1A	1B					A1
7	19	A29	1	1.66%	0.41	1A	1B					A1
7	20	H37	6	3.26%	0.39	4	5	6				H2
7	21	H41	6	3.26%	0.39	4	5	6				H1
7	22	A30	1	1.65%	0.41	1A	1B					A1
7	23	A31	1	1.65%	0.41	1A	1B					A1
7	24	A32	1	1.65%	0.41	1A	1B					A1

Assembly Parameters - Palisades Plant
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MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
8	1	XF17	4	1.50%	0.40	2A	2B					F1
8	2	XF18	4	1.51%	0.40	2A	2B					F1
8	3	EF0V	2	2.74%	0.42	2A	2B	3	4			D1
8	4	EF0W	2	2.74%	0.42	2A	2B	3	4			D1
8	5	EF1A	2	2.73%	0.42	2A	2B	3	4			D1
8	6	XF48	4	1.50%	0.40	2A	2B					F1
8	7	EF1C	2	2.74%	0.42	2A	2B	3	4			D1
8	8	EF1D	2	2.74%	0.42	2A	2B	3	4			D1
8	9	EF1F	2	2.74%	0.42	2A	2B	3	4			D1
8	10	EF1M	2	2.74%	0.42	2A	2B	3	4			D1
8	11	EF1N	2	2.73%	0.42	2A	2B	3	4			D1
8	12	XF54	4	1.50%	0.40	2A	2B					F1
8	13	XF55	4	1.50%	0.40	2A	2B					F1
8	14	EF1P	2	2.75%	0.41	2A	2B	3	4			D1
8	15	EF1Q	2	2.74%	0.42	2A	2B	3	4			D1
8	16	EF1S	2	2.75%	0.42	2A	2B	3	4			D1
8	17	EF1T	2	2.74%	0.42	2A	2B	3	4			D1
8	18	EF1U	2	2.75%	0.42	2A	2B	3	4			D1
8	19	EF1V	2	2.76%	0.41	2A	2B	3	4			D1
8	20	EF1W	2	2.75%	0.42	2A	2B	3	4			D1
8	21	EF1X	2	2.75%	0.42	2A	2B	3	4			D1
8	22	EF1Y	2	2.74%	0.42	2A	2B	3	4			D1
8	23	EF1Z	2	2.74%	0.42	2A	2B	3	4			D1
8	24	XF65	4	1.50%	0.40	2A	2B					F1

Assembly Parameters - Palisades Plant
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MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
9	1	XF03	4	1.51%	0.40	2A	2B					F1
9	2	XF05	4	1.51%	0.40	2A	2B					F1
9	3	EF08	2	2.74%	0.42	2A	2B	3	4			D1
9	4	EF03	2	2.74%	0.41	2A	2B	3	4			D1
9	5	EF05	2	2.74%	0.41	2A	2B	3	4			D1
9	6	XF56	4	1.50%	0.40	2A	2B					F1
9	7	EF09	2	2.75%	0.42	2A	2B	3	4			D1
9	8	EF17	2	2.74%	0.42	2A	2B	3	4			D1
9	9	EF0A	2	2.74%	0.42	2A	2B	3	4			D1
9	10	EF0M	2	2.74%	0.42	2A	2B	3	4			D1
9	11	EF0N	2	2.74%	0.42	2A	2B	3	4			D1
9	12	XF58	4	1.50%	0.40	2A	2B					F1
9	13	XF64	4	1.50%	0.40	2A	2B					F1
9	14	EF0J	2	2.75%	0.42	2A	2B	3	4			D1
9	15	EF0T	2	2.74%	0.42	2A	2B	3	4			D1
9	16	E01	3	3.05%	0.39	2A	2B	3	4			E1
9	17	EF0U	2	2.74%	0.42	2A	2B	3	4			D1
9	18	EF0D	2	2.74%	0.42	2A	2B	3	4			D1
9	19	EF0F	2	2.74%	0.42	2A	2B	3	4			D1
9	20	EF0Q	2	2.74%	0.41	2A	2B	3	4			D1
9	21	EF0R	2	2.74%	0.41	2A	2B	3	4			D1
9	22	EF0K	2	2.74%	0.42	2A	2B	3	4			D1
9	23	EF0L	2	2.75%	0.42	2A	2B	3	4			D1
9	24	XF66	4	1.51%	0.40	2A	2B					F1

Assembly Parameters - Palisades Plant
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MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
10	1	A04	1	1.65%	0.41	1A	1B					A1
10	2	A06	1	1.65%	0.41	1A	1B					A1
10	3	A07	1	1.65%	0.41	1A	1B					A1
10	4	H09	6	3.26%	0.39	4	5	6				H1
10	5	H30	6	3.26%	0.39	4	5	6				H2
10	6	A08	1	1.66%	0.41	1A	1B					A1
10	7	A09	1	1.65%	0.41	1A	1B					A1
10	8	H15	6	3.26%	0.39	4	5	6				H1
10	9	H18	6	3.26%	0.39	4	5	6				H1
10	10	H25	6	3.26%	0.39	4	5	6				H1
10	11	H60	6	3.26%	0.39	4	5	6				H1
10	12	A11	1	1.66%	0.41	1A	1B					A1
10	13	A13	1	1.66%	0.41	1A	1B					A1
10	14	H29	6	3.26%	0.39	4	5	6				H2
10	15	H32	6	3.26%	0.39	4	5	6				H1
10	16	H36	6	3.26%	0.39	4	5	6				H2
10	17	H40	6	3.26%	0.39	4	5	6				H1
10	18	A16	1	1.66%	0.41	1A	1B					A1
10	19	A17	1	1.66%	0.41	1A	1B					A1
10	20	H50	6	3.26%	0.39	4	5	6				H2
10	21	H51	6	3.26%	0.39	4	5	6				H2
10	22	A18	1	1.66%	0.41	1A	1B					A1
10	23	A19	1	1.65%	0.41	1A	1B					A1
10	24	A64	1	1.66%	0.41	1A	1B					A1

Assembly Parameters - Palisades Plant
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MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
11	1	XF32	4	1.50%	0.40	2A	2B					F1
11	2	XF33	4	1.50%	0.40	2A	2B					F1
11	3	XF34	4	1.50%	0.40	2A	2B					F1
11	4	I04	9	3.24%	0.40	5	6	7A	7B			I4
11	5	I05	9	3.24%	0.40	5	6	7A	7B			I4
11	6	XF35	4	1.50%	0.40	2A	2B					F1
11	7	XF36	4	1.50%	0.40	2A	2B					F1
11	8	I06	9	3.24%	0.40	5	6	7A	7B			I4
11	9	XF37	4	1.50%	0.40	2A	2B					F1
11	10	XF38	4	1.51%	0.40	2A	2B					F1
11	11	I16	7	3.26%	0.39	5	6	7A	7B			I3
11	12	XF39	4	1.50%	0.40	2A	2B					F1
11	13	XF40	4	1.51%	0.40	2A	2B					F1
11	14	I17	7	3.25%	0.39	5	6	7A	7B			I3
11	15	A40	1	1.65%	0.41	1A	1B					A1
11	16	H67	6	3.26%	0.39	4	5	6				H1
11	17	I32	7	3.25%	0.39	5	6	7A	7B			I1
11	18	A67	1	1.66%	0.41	1A	1B					A1
11	19	A43	1	1.66%	0.41	1A	1B					A1
11	20	I63	7	3.23%	0.39	5	6	7A	7B			I2
11	21	I64	7	3.23%	0.39	5	6	7A	7B			I2
11	22	A44	1	1.65%	0.41	1A	1B					A1
11	23	A45	1	1.65%	0.41	1A	1B					A1
11	24	A46	1	1.65%	0.41	1A	1B					A1

Assembly Parameters - Palisades Plant
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MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
12	1	XF41	4	1.50%	0.40	2A	2B					F1
12	2	XF42	4	1.50%	0.40	2A	2B					F1
12	3	XF43	4	1.51%	0.40	2A	2B					F1
12	4	I07	9	3.24%	0.40	5	6	7A	7B			I4
12	5	I08	9	3.24%	0.40	5	6	7A	7B			I4
12	6	XF44	4	1.51%	0.40	2A	2B					F1
12	7	XF45	4	1.50%	0.40	2A	2B					F1
12	8	I09	9	3.24%	0.40	5	6	7A	7B			I4
12	9	XF47	4	1.50%	0.40	2A	2B					F1
12	10	XF12	4	1.50%	0.40	2A	2B					F1
12	11	I18	7	3.25%	0.39	5	6	7A	7B			I3
12	12	XF49	4	1.50%	0.40	2A	2B					F1
12	13	XF50	4	1.50%	0.40	2A	2B					F1
12	14	I19	7	3.25%	0.39	5	6	7A	7B			I3
12	15	A48	1	1.65%	0.41	1A	1B					A1
12	16	H45	6	3.26%	0.39	4	5	6				H2
12	17	I33	7	3.25%	0.39	5	6	7A	7B			I1
12	18	A49	1	1.65%	0.41	1A	1B					A1
12	19	A50	1	1.65%	0.41	1A	1B					A1
12	20	I34	7	3.25%	0.39	5	6	7A	7B			I1
12	21	I35	7	3.25%	0.39	5	6	7A	7B			I1
12	22	A51	1	1.65%	0.41	1A	1B					A1
12	23	A34	1	1.65%	0.41	1A	1B					A1
12	24	A55	1	1.66%	0.41	1A	1B					A1

Assembly Parameters - Palisades Plant
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MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
13	1	XF52	4	1.50%	0.40	2A	2B					F1
13	2	XF13	4	1.50%	0.40	2A	2B					F1
13	3	XF14	4	1.50%	0.40	2A	2B					F1
13	4	I10	9	3.24%	0.40	5	6	7A	7B			I4
13	5	I11	9	3.24%	0.40	5	6	7A	7B			I4
13	6	XF07	4	1.51%	0.40	2A	2B					F1
13	7	XF06	4	1.51%	0.40	2A	2B					F1
13	8	I12	9	3.24%	0.40	5	6	7A	7B			I4
13	9	XF59	4	1.50%	0.40	2A	2B					F1
13	10	XF60	4	1.50%	0.40	2A	2B					F1
13	11	I20	7	3.25%	0.39	5	6	7A	7B			I3
13	12	XF61	4	1.50%	0.40	2A	2B					F1
13	13	XF62	4	1.50%	0.40	2A	2B					F1
13	14	I36	7	3.26%	0.39	5	6	7A	7B			I1
13	15	A56	1	1.65%	0.41	1A	1B					A1
13	16	H19	6	3.26%	0.39	4	5	6				H2
13	17	I65	7	3.23%	0.39	5	6	7A	7B			I2
13	18	XF19	4	1.50%	0.40	2A	2B					F1
13	19	A62	1	1.66%	0.41	1A	1B					A1
13	20	I66	7	3.23%	0.39	5	6	7A	7B			I2
13	21	I67	7	3.23%	0.39	5	6	7A	7B			I2
13	22	A63	1	1.65%	0.41	1A	1B					A1
13	23	A20	1	1.65%	0.41	1A	1B					A1
13	24	A66	1	1.66%	0.41	1A	1B					A1

Assembly Parameters - Palisades Plant
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MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
15	1	J33	8	3.26%	0.39	6	7A	7B	8			J1
15	2	J13	9	3.24%	0.40	6	7A	7B	8			J2
15	3	I62	7	3.23%	0.39	5	6	7A	7B			I2
15	4	K07	9	3.25%	0.40	7A	7B	8	9			K2
15	5	L29	10	3.22%	0.40	8	9	10				L1
15	6	XF68	4	1.50%	0.40	2A	2B					F1
15	7	J52	8	3.25%	0.39	6	7A	7B	8			J1
15	8	L35	10	3.22%	0.40	8	9	10				L1
15	9	I22	7	3.25%	0.39	5	6	7A	7B	9	10	I1h
15	10	I28	7	3.26%	0.39	5	6	7A	7B	9	10	I1h
15	11	L19	10	3.15%	0.40	8	9	10	11A	11B		L3S
15	12	J12	9	3.24%	0.40	6	7A	7B	8			J2
15	13	J30	8	3.25%	0.39	6	7A	7B	8			J1
15	14	L31	10	3.23%	0.40	8	9	10				L1
15	15	I26	7	3.26%	0.39	5	6	7A	7B	9	10	I1h
15	16	L08	10	3.20%	0.40	8	9	10	11A	11B		L2S
15	17	K01	9	3.24%	0.40	7A	7B	8	9			K2
15	18	K09	9	3.25%	0.40	7A	7B	8	9			K2
15	19	H61	6	3.23%	0.39	4	5	6				H3
15	20	H65	6	3.26%	0.39	4	5	6	8			H1S
15	21	L15	10	3.14%	0.40	8	9	10	11A	11B		L3S
15	22	J64	8	3.26%	0.39	6	7A	7B	8			J1
15	23	J65	8	3.26%	0.39	6	7A	7B	8			J1
15	24	J48	8	3.25%	0.39	6	7A	7B	8			J1

Assembly Parameters - Palisades Plant
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MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
16	1	J35	8	3.25%	0.39	6	7A	7B	8			J1
16	2	J17	9	3.24%	0.40	6	7A	7B	8			J2
16	3	I68	7	3.23%	0.39	5	6	7A	7B			I2
16	4	K02	9	3.25%	0.40	7A	7B	8	9			K2
16	5	L43	10	3.22%	0.40	8	9	10				L1
16	6	XF63	4	1.50%	0.40	2A	2B					F1
16	7	J09	9	3.24%	0.40	6	7A	7B	8			J2
16	8	L42	10	3.22%	0.40	8	9	10				L1
16	9	L05	10	3.20%	0.40	8	9	10	11A	11B		L2S
16	10	L18	10	3.15%	0.40	8	9	10	11A	11B		L3S
16	11	L32	10	3.23%	0.40	8	9	10				L1
16	12	J28	8	3.25%	0.39	6	7A	7B	8			J1
16	13	J47	8	3.25%	0.39	6	7A	7B	8			J1
16	14	L38	10	3.22%	0.40	8	9	10				L1
16	15	I27	7	3.26%	0.39	5	6	7A	7B	9	10	I1h
16	16	I45	7	3.25%	0.39	5	6	7A	7B	9	10	I1h
16	17	L39	10	3.23%	0.40	8	9	10				L1
16	18	K11	9	3.25%	0.40	7A	7B	8	9			K2
16	19	G36	5	3.00%	0.39	3	4	5				G2
16	20	H39	6	3.26%	0.39	4	5	6	8			H1S
16	21	L60	10	3.23%	0.40	8	9	10				L1
16	22	J63	8	3.25%	0.39	6	7A	7B	8			J1
16	23	J67	8	3.26%	0.39	6	7A	7B	8			J1
16	24	J51	8	3.26%	0.39	6	7A	7B	8			J1

Assembly Parameters - Palisades Plant
Attachment to VSC-03.3605

MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
17	1	J29	8	3.25%	0.39	6	7A	7B	8			J1
17	2	J14	9	3.24%	0.40	6	7A	7B	8			J2
17	3	I31	7	3.25%	0.39	5	6	7A	7B			I1
17	4	K05	9	3.24%	0.40	7A	7B	8	9			K2
17	5	L20	10	3.15%	0.40	8	9	10	11A	11B		L3S
17	6	XF04	4	1.51%	0.40	2A	2B					F1
17	7	J27	8	3.25%	0.39	6	7A	7B	8			J1
17	8	L13	10	3.14%	0.40	8	9	10	11A	11B		L3S
17	9	L11	10	3.20%	0.40	8	9	10	11A	11B		L2S
17	10	I50	7	3.25%	0.39	5	6	7A	7B	9	10	I1h
17	11	H31	6	3.26%	0.39	4	5	6	8			H1S
17	12	J46	8	3.25%	0.39	6	7A	7B	8			J1
17	13	J49	8	3.26%	0.39	6	7A	7B	8			J1
17	14	H59	6	3.26%	0.39	4	5	6	8			H1S
17	15	I23	7	3.25%	0.39	5	6	7A	7B	9	10	I1h
17	16	I47	7	3.25%	0.39	5	6	7A	7B	9	10	I1h
17	17	L53	10	3.23%	0.40	8	9	10				L1
17	18	K10	9	3.25%	0.40	7A	7B	8	9			K2
17	19	G52	5	3.00%	0.39	3	4	5				G2
17	20	H38	6	3.26%	0.39	4	5	6	8			H1S
17	21	L58	10	3.22%	0.40	8	9	10				L1
17	22	J62	8	3.25%	0.39	6	7A	7B	8			J1
17	23	J66	8	3.26%	0.39	6	7A	7B	8			J1
17	24	J21	8	3.25%	0.39	6	7A	7B	8			J1

Assembly Parameters - Palisades Plant
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MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
18	1	J34	8	3.25%	0.39	6	7A	7B	8			J1
18	2	EF0G	2	2.74%	0.42	2A	2B	3	4			D1
18	3	H47	6	3.26%	0.39	4	5	6				H2
18	4	K08	9	3.24%	0.40	7A	7B	8	9			K2
18	5	L14	10	3.15%	0.40	8	9	10	11A	11B		L3S
18	6	XF67	4	1.50%	0.40	2A	2B					F1
18	7	J25	8	3.25%	0.39	6	7A	7B	8			J1
18	8	L56	10	3.22%	0.40	8	9	10				L1
18	9	I48	7	3.26%	0.39	5	6	7A	7B	9	10	I1h
18	10	I52	7	3.25%	0.39	5	6	7A	7B	9	10	I1h
18	11	L36	10	3.22%	0.40	8	9	10				L1
18	12	J24	8	3.25%	0.39	6	7A	7B	8			J1
18	13	J45	8	3.26%	0.39	6	7A	7B	8			J1
18	14	L45	10	3.23%	0.40	8	9	10				L1
18	15	I21	7	3.26%	0.39	5	6	7A	7B	9	10	I1h
18	16	I49	7	3.25%	0.39	5	6	7A	7B	9	10	I1h
18	17	L59	10	3.22%	0.40	8	9	10				L1
18	18	J32	8	3.26%	0.39	6	7A	7B	8			J1
18	19	G49	5	3.00%	0.39	3	4	5				G2
18	20	H03	6	3.26%	0.39	4	5	6	8			H1S
18	21	L17	10	3.14%	0.40	8	9	10	11A	11B		L3S
18	22	J68	8	3.25%	0.39	6	7A	7B	8			J1
18	23	J61	8	3.26%	0.39	6	7A	7B	8			J1
18	24	J22	8	3.26%	0.39	6	7A	7B	8			J1

Assembly Parameters - Palisades Plant
Attachment to VSC-03.3605

MSB I.D.	MSB Location[1]	Assembly ID	FA Type[2]	Initial Enrichment (% U-235)	Initial Fuel Mass (MTU)	1st Cycle ID	2nd Cycle ID	3rd Cycle ID	4th Cycle ID	5th Cycle ID	6th Cycle ID	Fuel Sub-Type
19	1	J36	8	3.25%	0.39	6	7A	7B	8			J1
19	2	EF0S	2	2.74%	0.42	2A	2B	3	4			D1
19	3	H11	6	3.26%	0.39	4	5	6				H1
19	4	K06	9	3.24%	0.40	7A	7B	8	9			K2
19	5	L16	10	3.14%	0.40	8	9	10	11A	11B		L3S
19	6	XF01	4	1.50%	0.40	2A	2B					F1
19	7	J11	9	3.24%	0.40	6	7A	7B	8			J2
19	8	L49	10	3.22%	0.40	8	9	10				L1
19	9	I46	7	3.26%	0.39	5	6	7A	7B	9	10	I1h
19	10	I25	7	3.25%	0.39	5	6	7A	7B	9	10	I1h
19	11	L50	10	3.22%	0.40	8	9	10				L1
19	12	J26	8	3.25%	0.39	6	7A	7B	8			J1
19	13	J50	8	3.26%	0.39	6	7A	7B	8			J1
19	14	L52	10	3.22%	0.40	8	9	10				L1
19	15	I51	7	3.25%	0.39	5	6	7A	7B	9	10	I1h
19	16	H01	6	3.26%	0.39	4	5	6	8			H1S
19	17	L57	10	3.22%	0.40	8	9	10				L1
19	18	J31	8	3.26%	0.39	6	7A	7B	8			J1
19	19	G19	5	3.00%	0.39	3	4	5				G2
19	20	K03	9	3.24%	0.40	7A	7B	8	9			K2
19	21	L46	10	3.23%	0.40	8	9	10				L1
19	22	I61	7	3.23%	0.39	5	6	7A	7B			I2
19	23	J10	9	3.24%	0.40	6	7A	7B	8			J2
19	24	J23	8	3.25%	0.39	6	7A	7B	8			J1

Assembly Parameters - Palisades Plant
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		Asy Cyc:	1		2		3		4		5		6	
Cask	**Asbly**		**BU Init**	**BU Fin**	**BU Init**	**BU Fin**	**BU Init**	**BU Fin**	**BU Init**	**BU Fin**	**BU Init**	**BU Fin**	**BU Init**	**BU Fin**
1	1		0.000	10.464	10.464	22.791	22.791	33.997	33.997	0.000	0.000	0.000	0.000	0.000
1	2		0.000	10.464	10.464	22.791	22.791	33.997	33.997	0.000	0.000	0.000	0.000	0.000
1	3		0.000	10.464	10.464	22.791	22.791	33.997	33.997	0.000	0.000	0.000	0.000	0.000
1	4		0.000	8.176	8.176	19.468	19.468	31.414	31.414	0.000	0.000	0.000	0.000	0.000
1	5		0.000	10.464	10.464	22.791	22.791	33.997	33.997	0.000	0.000	0.000	0.000	0.000
1	6		0.000	10.464	10.464	22.791	22.791	33.997	33.997	0.000	0.000	0.000	0.000	0.000
1	7		0.000	10.464	10.464	22.791	22.791	33.997	33.997	0.000	0.000	0.000	0.000	0.000
1	8		0.000	10.464	10.464	22.791	22.791	33.997	33.997	0.000	0.000	0.000	0.000	0.000
1	9		0.000	10.519	10.519	21.804	21.804	33.517	33.517	0.000	0.000	0.000	0.000	0.000
1	10		0.000	10.464	10.464	22.791	22.791	33.997	33.997	0.000	0.000	0.000	0.000	0.000
1	11		0.000	10.519	10.519	21.804	21.804	33.517	33.517	0.000	0.000	0.000	0.000	0.000
1	12		0.000	8.176	8.176	19.468	19.468	31.414	31.414	0.000	0.000	0.000	0.000	0.000
1	13		0.000	6.851	6.851	19.135	19.135	30.972	30.972	0.000	0.000	0.000	0.000	0.000
1	14		0.000	10.611	10.611	21.803	21.803	32.723	32.723	0.000	0.000	0.000	0.000	0.000
1	15		0.000	10.611	10.611	21.803	21.803	32.723	32.723	0.000	0.000	0.000	0.000	0.000
1	16		0.000	6.851	6.851	19.135	19.135	30.972	30.972	0.000	0.000	0.000	0.000	0.000
1	17		0.000	10.791	10.791	21.732	21.732	32.410	32.410	0.000	0.000	0.000	0.000	0.000
1	18		0.000	13.092	13.092	23.754	23.754	34.930	34.930	0.000	0.000	0.000	0.000	0.000
1	19		0.000	10.791	10.791	21.732	21.732	32.410	32.410	0.000	0.000	0.000	0.000	0.000
1	20		0.000	6.851	6.851	19.135	19.135	30.972	30.972	0.000	0.000	0.000	0.000	0.000
1	21		0.000	10.791	10.791	21.732	21.732	32.410	32.410	0.000	0.000	0.000	0.000	0.000
1	22		0.000	10.791	10.791	21.732	21.732	32.410	32.410	0.000	0.000	0.000	0.000	0.000
1	23		0.000	6.851	6.851	19.135	19.135	30.972	30.972	0.000	0.000	0.000	0.000	0.000
1	24		0.000	10.611	10.611	21.803	21.803	32.723	32.723	0.000	0.000	0.000	0.000	0.000
2	1		0.000	10.611	10.611	21.803	21.803	32.723	32.723	0.000	0.000	0.000	0.000	0.000
2	2		0.000	8.176	8.176	19.468	19.468	31.414	31.414	0.000	0.000	0.000	0.000	0.000
2	3		0.000	13.092	13.092	23.754	23.754	34.930	34.930	0.000	0.000	0.000	0.000	0.000
2	4		0.000	8.176	8.176	19.468	19.468	31.414	31.414	0.000	0.000	0.000	0.000	0.000
2	5		0.000	10.519	10.519	21.804	21.804	33.517	33.517	0.000	0.000	0.000	0.000	0.000
2	6		0.000	10.519	10.519	21.804	21.804	33.517	33.517	0.000	0.000	0.000	0.000	0.000
2	7		0.000	10.519	10.519	21.804	21.804	33.517	33.517	0.000	0.000	0.000	0.000	0.000
2	8		0.000	8.176	8.176	19.468	19.468	31.414	31.414	0.000	0.000	0.000	0.000	0.000
2	9		0.000	13.092	13.092	23.754	23.754	34.930	34.930	0.000	0.000	0.000	0.000	0.000
2	10		0.000	8.176	8.176	19.468	19.468	31.414	31.414	0.000	0.000	0.000	0.000	0.000
2	11		0.000	10.611	10.611	21.803	21.803	32.723	32.723	0.000	0.000	0.000	0.000	0.000
2	12		0.000	10.611	10.611	21.803	21.803	32.723	32.723	0.000	0.000	0.000	0.000	0.000
2	13		0.000	10.791	10.791	21.732	21.732	32.410	32.410	0.000	0.000	0.000	0.000	0.000
2	14		0.000	10.791	10.791	21.732	21.732	32.410	32.410	0.000	0.000	0.000	0.000	0.000
2	15		0.000	6.851	6.851	19.135	19.135	30.972	30.972	0.000	0.000	0.000	0.000	0.000
2	16		0.000	13.092	13.092	23.754	23.754	34.930	34.930	0.000	0.000	0.000	0.000	0.000

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		Asy Cyc:	1		2		3		4		5		6	
2	17		0.000	10.791	10.791	21.732	21.732	32.410	32.410	0.000	0.000	0.000	0.000	0.000
2	18		0.000	10.791	10.791	21.732	21.732	32.410	32.410	0.000	0.000	0.000	0.000	0.000
2	19		0.000	13.092	13.092	23.754	23.754	34.930	34.930	0.000	0.000	0.000	0.000	0.000
2	20		0.000	13.092	13.092	23.754	23.754	34.930	34.930	0.000	0.000	0.000	0.000	0.000
2	21		0.000	6.851	6.851	19.135	19.135	30.972	30.972	0.000	0.000	0.000	0.000	0.000
2	22		0.000	13.092	13.092	23.754	23.754	34.930	34.930	0.000	0.000	0.000	0.000	0.000
2	23		0.000	10.611	10.611	21.803	21.803	32.723	32.723	0.000	0.000	0.000	0.000	0.000
2	24		0.000	6.851	6.851	19.135	19.135	30.972	30.972	0.000	0.000	0.000	0.000	0.000
3	1		0.000	8.815	8.815	9.181	9.181	21.245	21.245	30.261	30.261	0.000	0.000	0.000
3	2		0.000	12.953	12.953	13.736	13.736	24.295	24.295	33.028	33.028	0.000	0.000	0.000
3	3		0.000	12.953	12.953	13.736	13.736	24.295	24.295	33.028	33.028	0.000	0.000	0.000
3	4		0.000	13.976	13.976	24.709	24.709	35.117	35.117	0.000	0.000	0.000	0.000	0.000
3	5		0.000	11.651	11.651	12.990	12.990	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	6		0.000	14.897	14.897	15.535	15.535	26.360	26.360	35.333	35.333	0.000	0.000	0.000
3	7		0.000	14.897	14.897	15.535	15.535	26.360	26.360	35.333	35.333	0.000	0.000	0.000
3	8		0.000	8.176	8.176	19.468	19.468	31.414	31.414	0.000	0.000	0.000	0.000	0.000
3	9		0.000	11.997	11.997	13.366	13.366	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	10		0.000	12.339	12.339	13.911	13.911	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	11		0.000	11.651	11.651	12.990	12.990	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	12		0.000	6.356	6.356	6.618	6.618	19.103	19.103	28.129	28.129	0.000	0.000	0.000
3	13		0.000	7.201	7.201	7.518	7.518	19.637	19.637	28.825	28.825	0.000	0.000	0.000
3	14		0.000	13.976	13.976	24.709	24.709	35.117	35.117	0.000	0.000	0.000	0.000	0.000
3	15		0.000	12.177	12.177	13.626	13.626	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	16		0.000	12.177	12.177	13.626	13.626	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	17		0.000	13.976	13.976	24.709	24.709	35.117	35.117	0.000	0.000	0.000	0.000	0.000
3	18		0.000	8.815	8.815	9.181	9.181	21.245	21.245	30.261	30.261	0.000	0.000	0.000
3	19		0.000	6.356	6.356	6.618	6.618	19.103	19.103	28.129	28.129	0.000	0.000	0.000
3	20		0.000	12.920	12.920	24.563	24.563	35.173	35.173	0.000	0.000	0.000	0.000	0.000
3	21		0.000	12.920	12.920	24.563	24.563	35.173	35.173	0.000	0.000	0.000	0.000	0.000
3	22		0.000	12.953	12.953	13.736	13.736	24.295	24.295	33.028	33.028	0.000	0.000	0.000
3	23		0.000	8.815	8.815	9.181	9.181	21.245	21.245	30.261	30.261	0.000	0.000	0.000
3	24		0.000	10.504	10.504	11.101	11.101	21.684	21.684	30.354	30.354	0.000	0.000	0.000
4	1		0.000	9.346	9.346	9.835	9.835	21.411	21.411	30.344	30.344	0.000	0.000	0.000
4	2		0.000	8.815	8.815	9.181	9.181	21.245	21.245	30.261	30.261	0.000	0.000	0.000
4	3		0.000	10.504	10.504	11.101	11.101	21.651	21.651	30.585	30.585	0.000	0.000	0.000
4	4		0.000	13.976	13.976	24.709	24.709	35.117	35.117	0.000	0.000	0.000	0.000	0.000
4	5		0.000	12.177	12.177	13.626	13.626	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	6		0.000	10.504	10.504	11.101	11.101	21.651	21.651	30.585	30.585	0.000	0.000	0.000
4	7		0.000	9.346	9.346	9.835	9.835	21.411	21.411	30.344	30.344	0.000	0.000	0.000
4	8		0.000	13.976	13.976	24.709	24.709	35.117	35.117	0.000	0.000	0.000	0.000	0.000
4	9		0.000	12.177	12.177	13.626	13.626	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Assembly Parameters - Palisades Plant
Attachment to VSC-03.3605

		Asy Cyc:	1		2		3		4		5		6	
4	10		0.000	11.997	11.997	13.366	13.366	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	11		0.000	11.624	11.624	13.110	13.110	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	12		0.000	10.504	10.504	11.101	11.101	21.684	21.684	30.354	30.354	0.000	0.000	0.000
4	13		0.000	14.457	14.457	15.011	15.011	24.856	24.856	33.630	33.630	0.000	0.000	0.000
4	14		0.000	10.519	10.519	21.804	21.804	33.517	33.517	0.000	0.000	0.000	0.000	0.000
4	15		0.000	11.997	11.997	13.366	13.366	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	16		0.000	14.897	14.897	15.535	15.535	26.360	26.360	35.333	35.333	0.000	0.000	0.000
4	17		0.000	13.092	13.092	23.754	23.754	34.930	34.930	0.000	0.000	0.000	0.000	0.000
4	18		0.000	14.457	14.457	15.011	15.011	24.856	24.856	33.630	33.630	0.000	0.000	0.000
4	19		0.000	10.916	10.916	11.313	11.313	22.620	22.620	31.787	31.787	0.000	0.000	0.000
4	20		0.000	10.519	10.519	21.804	21.804	33.517	33.517	0.000	0.000	0.000	0.000	0.000
4	21		0.000	12.920	12.920	24.563	24.563	35.173	35.173	0.000	0.000	0.000	0.000	0.000
4	22		0.000	8.815	8.815	9.181	9.181	21.245	21.245	30.261	30.261	0.000	0.000	0.000
4	23		0.000	8.815	8.815	9.181	9.181	21.245	21.245	30.261	30.261	0.000	0.000	0.000
4	24		0.000	11.651	11.651	12.990	12.990	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	1		0.000	11.997	11.997	13.366	13.366	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	2		0.000	12.697	12.697	14.304	14.304	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	3		0.000	11.651	11.651	12.990	12.990	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	4		0.000	14.629	14.629	25.056	25.056	26.277	26.277	34.751	34.751	0.000	0.000	0.000
5	5		0.000	14.629	14.629	25.056	25.056	26.277	26.277	34.751	34.751	0.000	0.000	0.000
5	6		0.000	11.997	11.997	13.366	13.366	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	7		0.000	12.826	12.826	13.873	13.873	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	8		0.000	14.629	14.629	25.056	25.056	26.277	26.277	34.751	34.751	0.000	0.000	0.000
5	9		0.000	12.826	12.826	13.873	13.873	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	10		0.000	11.624	11.624	13.110	13.110	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	11		0.000	15.390	15.390	26.548	26.548	27.784	27.784	36.109	36.109	0.000	0.000	0.000
5	12		0.000	11.651	11.651	12.990	12.990	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	13		0.000	10.554	10.554	11.837	11.837	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	14		0.000	15.390	15.390	26.548	26.548	27.661	27.661	36.069	36.069	0.000	0.000	0.000
5	15		0.000	6.496	6.496	11.100	11.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	16		0.000	10.824	10.824	25.247	25.247	34.932	34.932	0.000	0.000	0.000	0.000	0.000
5	17		0.000	15.390	15.390	26.548	26.548	27.661	27.661	36.069	36.069	0.000	0.000	0.000
5	18		0.000	6.839	6.839	11.622	11.622	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	19		0.000	6.496	6.496	11.100	11.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	20		0.000	11.714	11.714	23.236	23.236	24.624	24.624	34.678	34.678	0.000	0.000	0.000
5	21		0.000	11.714	11.714	23.236	23.236	24.624	24.624	34.678	34.678	0.000	0.000	0.000
5	22		0.000	6.837	6.837	11.607	11.607	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	23		0.000	6.097	6.097	10.318	10.318	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	24		0.000	6.371	6.371	10.830	10.830	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	1		0.000	6.837	6.837	11.607	11.607	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	2		0.000	6.097	6.097	10.318	10.318	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Assembly Parameters - Palisades Plant
Attachment to VSC-03.3605

		Asy Cyc:	1		2		3		4		5		6	
6	3		0.000	6.837	6.837	11.607	11.607	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	4		0.000	13.275	13.275	26.294	26.294	35.215	35.215	0.000	0.000	0.000	0.000	0.000
6	5		0.000	13.275	13.275	26.294	26.294	35.215	35.215	0.000	0.000	0.000	0.000	0.000
6	6		0.000	6.371	6.371	10.830	10.830	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	7		0.000	6.097	6.097	10.318	10.318	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	8		0.000	13.275	13.275	28.169	28.169	36.620	36.620	0.000	0.000	0.000	0.000	0.000
6	9		0.000	11.212	11.212	25.794	25.794	35.205	35.205	0.000	0.000	0.000	0.000	0.000
6	10		0.000	11.212	11.212	25.794	25.794	35.205	35.205	0.000	0.000	0.000	0.000	0.000
6	11		0.000	11.212	11.212	25.794	25.794	35.205	35.205	0.000	0.000	0.000	0.000	0.000
6	12		0.000	6.490	6.490	10.751	10.751	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	13		0.000	6.467	6.467	11.080	11.080	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	14		0.000	11.212	11.212	25.794	25.794	35.205	35.205	0.000	0.000	0.000	0.000	0.000
6	15		0.000	10.824	10.824	25.247	25.247	34.932	34.932	0.000	0.000	0.000	0.000	0.000
6	16		0.000	10.106	10.106	24.598	24.598	34.143	34.143	0.000	0.000	0.000	0.000	0.000
6	17		0.000	12.927	12.927	26.164	26.164	35.078	35.078	0.000	0.000	0.000	0.000	0.000
6	18		0.000	6.485	6.485	11.056	11.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	19		0.000	6.485	6.485	11.056	11.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	20		0.000	12.927	12.927	26.164	26.164	35.078	35.078	0.000	0.000	0.000	0.000	0.000
6	21		0.000	12.927	12.927	26.164	26.164	35.078	35.078	0.000	0.000	0.000	0.000	0.000
6	22		0.000	6.837	6.837	11.607	11.607	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	23		0.000	6.837	6.837	11.607	11.607	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	24		0.000	6.496	6.496	11.100	11.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	1		0.000	6.097	6.097	10.318	10.318	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	2		0.000	6.097	6.097	10.318	10.318	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	3		0.000	6.490	6.490	10.751	10.751	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	4		0.000	9.998	9.998	24.328	24.328	34.080	34.080	0.000	0.000	0.000	0.000	0.000
7	5		0.000	10.824	10.824	25.247	25.247	34.932	34.932	0.000	0.000	0.000	0.000	0.000
7	6		0.000	6.485	6.485	11.056	11.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	7		0.000	6.944	6.944	11.717	11.717	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	8		0.000	11.212	11.212	25.794	25.794	35.205	35.205	0.000	0.000	0.000	0.000	0.000
7	9		0.000	10.824	10.824	25.247	25.247	34.932	34.932	0.000	0.000	0.000	0.000	0.000
7	10		0.000	13.275	13.275	28.169	28.169	36.620	36.620	0.000	0.000	0.000	0.000	0.000
7	11		0.000	12.228	12.228	26.593	26.593	36.337	36.337	0.000	0.000	0.000	0.000	0.000
7	12		0.000	6.944	6.944	11.717	11.717	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	13		0.000	6.944	6.944	11.717	11.717	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	14		0.000	13.275	13.275	28.169	28.169	36.620	36.620	0.000	0.000	0.000	0.000	0.000
7	15		0.000	11.212	11.212	25.794	25.794	35.205	35.205	0.000	0.000	0.000	0.000	0.000
7	16		0.000	9.998	9.998	24.328	24.328	34.080	34.080	0.000	0.000	0.000	0.000	0.000
7	17		0.000	13.275	13.275	26.294	26.294	35.215	35.215	0.000	0.000	0.000	0.000	0.000
7	18		0.000	6.097	6.097	10.318	10.318	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	19		0.000	6.596	6.596	11.062	11.062	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Assembly Parameters - Palisades Plant
Attachment to VSC-03.3605

		Asy Cyc:	1		2		3		4		5		6	
7	20		0.000	12.228	12.228	26.593	26.593	36.337	36.337	0.000	0.000	0.000	0.000	0.000
7	21		0.000	10.824	10.824	25.247	25.247	34.932	34.932	0.000	0.000	0.000	0.000	0.000
7	22		0.000	6.371	6.371	10.830	10.830	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	23		0.000	6.371	6.371	10.830	10.830	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	24		0.000	6.596	6.596	11.062	11.062	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	1		0.000	11.997	11.997	13.366	13.366	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	2		0.000	10.554	10.554	11.837	11.837	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	3		0.000	14.457	14.457	15.011	15.011	24.856	24.856	33.630	33.630	0.000	0.000	0.000
8	4		0.000	10.916	10.916	11.313	11.313	22.620	22.620	31.787	31.787	0.000	0.000	0.000
8	5		0.000	9.346	9.346	9.835	9.835	21.411	21.411	30.344	30.344	0.000	0.000	0.000
8	6		0.000	13.092	13.092	14.699	14.699	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	7		0.000	9.346	9.346	9.835	9.835	21.411	21.411	30.344	30.344	0.000	0.000	0.000
8	8		0.000	9.346	9.346	9.835	9.835	21.411	21.411	30.344	30.344	0.000	0.000	0.000
8	9		0.000	6.356	6.356	6.618	6.618	19.103	19.103	28.129	28.129	0.000	0.000	0.000
8	10		0.000	12.953	12.953	13.736	13.736	24.295	24.295	33.028	33.028	0.000	0.000	0.000
8	11		0.000	10.504	10.504	11.101	11.101	21.684	21.684	30.354	30.354	0.000	0.000	0.000
8	12		0.000	12.826	12.826	13.873	13.873	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	13		0.000	12.339	12.339	13.911	13.911	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	14		0.000	7.201	7.201	7.518	7.518	19.637	19.637	28.825	28.825	0.000	0.000	0.000
8	15		0.000	10.916	10.916	11.313	11.313	22.620	22.620	31.787	31.787	0.000	0.000	0.000
8	16		0.000	9.346	9.346	9.835	9.835	21.411	21.411	30.344	30.344	0.000	0.000	0.000
8	17		0.000	10.916	10.916	11.313	11.313	22.620	22.620	31.787	31.787	0.000	0.000	0.000
8	18		0.000	12.953	12.953	13.736	13.736	24.295	24.295	33.028	33.028	0.000	0.000	0.000
8	19		0.000	9.346	9.346	9.835	9.835	21.411	21.411	30.344	30.344	0.000	0.000	0.000
8	20		0.000	10.916	10.916	11.313	11.313	22.620	22.620	31.787	31.787	0.000	0.000	0.000
8	21		0.000	7.201	7.201	7.518	7.518	19.637	19.637	28.825	28.825	0.000	0.000	0.000
8	22		0.000	10.504	10.504	11.101	11.101	21.651	21.651	30.585	30.585	0.000	0.000	0.000
8	23		0.000	10.504	10.504	11.101	11.101	21.651	21.651	30.585	30.585	0.000	0.000	0.000
8	24		0.000	11.624	11.624	13.110	13.110	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	1		0.000	12.177	12.177	13.626	13.626	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	2		0.000	12.339	12.339	13.911	13.911	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	3		0.000	7.201	7.201	7.518	7.518	19.637	19.637	28.825	28.825	0.000	0.000	0.000
9	4		0.000	8.815	8.815	9.181	9.181	21.245	21.245	30.261	30.261	0.000	0.000	0.000
9	5		0.000	9.346	9.346	9.835	9.835	21.411	21.411	30.344	30.344	0.000	0.000	0.000
9	6		0.000	11.997	11.997	13.366	13.366	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	7		0.000	7.201	7.201	7.518	7.518	19.637	19.637	28.825	28.825	0.000	0.000	0.000
9	8		0.000	12.953	12.953	13.736	13.736	24.295	24.295	33.028	33.028	0.000	0.000	0.000
9	9		0.000	7.201	7.201	7.518	7.518	19.637	19.637	28.825	28.825	0.000	0.000	0.000
9	10		0.000	12.953	12.953	13.736	13.736	24.295	24.295	33.028	33.028	0.000	0.000	0.000
9	11		0.000	10.504	10.504	11.101	11.101	21.684	21.684	30.354	30.354	0.000	0.000	0.000
9	12		0.000	12.177	12.177	13.626	13.626	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Assembly Parameters - Palisades Plant
Attachment to VSC-03.3605

		Asy Cyc:	1		2		3		4		5		6	
9	13		0.000	12.393	12.393	13.989	13.989	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	14		0.000	12.953	12.953	13.736	13.736	24.295	24.295	33.028	33.028	0.000	0.000	0.000
9	15		0.000	10.916	10.916	11.313	11.313	22.620	22.620	31.787	31.787	0.000	0.000	0.000
9	16		0.000	14.897	14.897	15.535	15.535	26.360	26.360	35.333	35.333	0.000	0.000	0.000
9	17		0.000	14.457	14.457	15.011	15.011	24.856	24.856	33.630	33.630	0.000	0.000	0.000
9	18		0.000	6.356	6.356	6.618	6.618	19.103	19.103	28.129	28.129	0.000	0.000	0.000
9	19		0.000	6.356	6.356	6.618	6.618	19.103	19.103	28.129	28.129	0.000	0.000	0.000
9	20		0.000	10.916	10.916	11.313	11.313	22.620	22.620	31.787	31.787	0.000	0.000	0.000
9	21		0.000	10.916	10.916	11.313	11.313	22.620	22.620	31.787	31.787	0.000	0.000	0.000
9	22		0.000	6.356	6.356	6.618	6.618	19.103	19.103	28.129	28.129	0.000	0.000	0.000
9	23		0.000	6.356	6.356	6.618	6.618	19.103	19.103	28.129	28.129	0.000	0.000	0.000
9	24		0.000	11.651	11.651	12.990	12.990	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	1		0.000	6.496	6.496	11.100	11.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	2		0.000	6.490	6.490	10.751	10.751	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	3		0.000	6.485	6.485	11.056	11.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	4		0.000	10.824	10.824	25.247	25.247	34.932	34.932	0.000	0.000	0.000	0.000	0.000
10	5		0.000	13.275	13.275	26.294	26.294	35.215	35.215	0.000	0.000	0.000	0.000	0.000
10	6		0.000	6.837	6.837	11.607	11.607	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	7		0.000	6.837	6.837	11.607	11.607	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	8		0.000	11.212	11.212	25.794	25.794	35.205	35.205	0.000	0.000	0.000	0.000	0.000
10	9		0.000	10.824	10.824	25.247	25.247	34.932	34.932	0.000	0.000	0.000	0.000	0.000
10	10		0.000	9.998	9.998	24.328	24.328	34.080	34.080	0.000	0.000	0.000	0.000	0.000
10	11		0.000	9.998	9.998	24.328	24.328	34.080	34.080	0.000	0.000	0.000	0.000	0.000
10	12		0.000	6.485	6.485	11.056	11.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	13		0.000	6.944	6.944	11.717	11.717	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	14		0.000	12.228	12.228	26.593	26.593	36.337	36.337	0.000	0.000	0.000	0.000	0.000
10	15		0.000	10.106	10.106	24.598	24.598	34.143	34.143	0.000	0.000	0.000	0.000	0.000
10	16		0.000	12.228	12.228	26.593	26.593	36.337	36.337	0.000	0.000	0.000	0.000	0.000
10	17		0.000	10.824	10.824	25.247	25.247	34.932	34.932	0.000	0.000	0.000	0.000	0.000
10	18		0.000	6.485	6.485	11.056	11.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	19		0.000	6.490	6.490	10.751	10.751	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	20		0.000	12.228	12.228	26.593	26.593	36.337	36.337	0.000	0.000	0.000	0.000	0.000
10	21		0.000	12.228	12.228	26.593	26.593	36.337	36.337	0.000	0.000	0.000	0.000	0.000
10	22		0.000	6.596	6.596	11.062	11.062	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	23		0.000	6.596	6.596	11.062	11.062	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	24		0.000	6.496	6.496	11.100	11.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	1		0.000	12.697	12.697	14.304	14.304	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	2		0.000	13.092	13.092	14.699	14.699	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	3		0.000	10.554	10.554	11.837	11.837	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	4		0.000	14.629	14.629	25.056	25.056	26.277	26.277	34.751	34.751	0.000	0.000	0.000
11	5		0.000	14.325	14.325	25.579	25.579	26.812	26.812	35.673	35.673	0.000	0.000	0.000

Assembly Parameters - Palisades Plant
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		Asy Cyc:	1		2		3		4		5		6	
11	6		0.000	11.624	11.624	13.110	13.110	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	7		0.000	12.339	12.339	13.911	13.911	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	8		0.000	14.325	14.325	25.579	25.579	26.812	26.812	35.673	35.673	0.000	0.000	0.000
11	9		0.000	12.339	12.339	13.911	13.911	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	10		0.000	11.624	11.624	13.110	13.110	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	11		0.000	15.390	15.390	26.548	26.548	27.784	27.784	36.109	36.109	0.000	0.000	0.000
11	12		0.000	10.554	10.554	11.837	11.837	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	13		0.000	12.339	12.339	13.911	13.911	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	14		0.000	15.390	15.390	26.548	26.548	27.784	27.784	36.109	36.109	0.000	0.000	0.000
11	15		0.000	6.596	6.596	11.062	11.062	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	16		0.000	9.998	9.998	24.328	24.328	34.080	34.080	0.000	0.000	0.000	0.000	0.000
11	17		0.000	11.714	11.714	23.236	23.236	24.624	24.624	34.678	34.678	0.000	0.000	0.000
11	18		0.000	6.097	6.097	10.318	10.318	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	19		0.000	6.496	6.496	11.100	11.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	20		0.000	12.768	12.768	24.199	24.199	25.526	25.526	35.141	35.141	0.000	0.000	0.000
11	21		0.000	12.768	12.768	24.199	24.199	25.526	25.526	35.141	35.141	0.000	0.000	0.000
11	22		0.000	6.944	6.944	11.717	11.717	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	23		0.000	6.839	6.839	11.622	11.622	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	24		0.000	6.839	6.839	11.622	11.622	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	1		0.000	12.826	12.826	13.873	13.873	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	2		0.000	12.393	12.393	13.989	13.989	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	3		0.000	10.554	10.554	11.837	11.837	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	4		0.000	14.325	14.325	25.579	25.579	26.812	26.812	35.673	35.673	0.000	0.000	0.000
12	5		0.000	14.325	14.325	25.579	25.579	26.812	26.812	35.673	35.673	0.000	0.000	0.000
12	6		0.000	12.393	12.393	13.989	13.989	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	7		0.000	13.092	13.092	14.699	14.699	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	8		0.000	14.325	14.325	25.579	25.579	26.812	26.812	35.673	35.673	0.000	0.000	0.000
12	9		0.000	12.826	12.826	13.873	13.873	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	10		0.000	12.697	12.697	14.304	14.304	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	11		0.000	15.390	15.390	26.548	26.548	27.661	27.661	36.069	36.069	0.000	0.000	0.000
12	12		0.000	12.697	12.697	14.304	14.304	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	13		0.000	10.554	10.554	11.837	11.837	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	14		0.000	15.390	15.390	26.548	26.548	27.661	27.661	36.069	36.069	0.000	0.000	0.000
12	15		0.000	6.496	6.496	11.100	11.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	16		0.000	12.228	12.228	26.593	26.593	36.337	36.337	0.000	0.000	0.000	0.000	0.000
12	17		0.000	11.714	11.714	23.236	23.236	24.624	24.624	34.678	34.678	0.000	0.000	0.000
12	18		0.000	6.490	6.490	10.751	10.751	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	19		0.000	6.596	6.596	11.062	11.062	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	20		0.000	11.714	11.714	23.236	23.236	24.624	24.624	34.678	34.678	0.000	0.000	0.000
12	21		0.000	11.714	11.714	23.236	23.236	24.624	24.624	34.678	34.678	0.000	0.000	0.000
12	22		0.000	6.596	6.596	11.062	11.062	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Assembly Parameters - Palisades Plant
Attachment to VSC-03.3605

		Asy Cyc:	1		2		3		4		5		6	
12	23		0.000	6.097	6.097	10.318	10.318	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	24		0.000	6.944	6.944	11.717	11.717	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	1		0.000	10.554	10.554	11.837	11.837	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	2		0.000	12.826	12.826	13.873	13.873	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	3		0.000	12.339	12.339	13.911	13.911	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	4		0.000	14.325	14.325	25.579	25.579	26.812	26.812	35.673	35.673	0.000	0.000	0.000
13	5		0.000	14.325	14.325	25.579	25.579	26.812	26.812	35.673	35.673	0.000	0.000	0.000
13	6		0.000	12.177	12.177	13.626	13.626	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	7		0.000	12.177	12.177	13.626	13.626	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	8		0.000	14.325	14.325	25.579	25.579	26.812	26.812	35.673	35.673	0.000	0.000	0.000
13	9		0.000	11.624	11.624	13.110	13.110	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	10		0.000	11.651	11.651	12.990	12.990	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	11		0.000	15.390	15.390	26.548	26.548	27.784	27.784	36.109	36.109	0.000	0.000	0.000
13	12		0.000	10.554	10.554	11.837	11.837	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	13		0.000	12.393	12.393	13.989	13.989	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	14		0.000	11.714	11.714	23.236	23.236	24.624	24.624	34.678	34.678	0.000	0.000	0.000
13	15		0.000	6.944	6.944	11.717	11.717	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	16		0.000	12.228	12.228	26.593	26.593	36.337	36.337	0.000	0.000	0.000	0.000	0.000
13	17		0.000	12.768	12.768	24.199	24.199	25.526	25.526	35.141	35.141	0.000	0.000	0.000
13	18		0.000	11.624	11.624	13.110	13.110	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	19		0.000	6.485	6.485	11.056	11.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	20		0.000	12.768	12.768	24.199	24.199	25.526	25.526	35.141	35.141	0.000	0.000	0.000
13	21		0.000	12.768	12.768	24.199	24.199	25.526	25.526	35.141	35.141	0.000	0.000	0.000
13	22		0.000	6.490	6.490	10.751	10.751	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	23		0.000	6.490	6.490	10.751	10.751	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	24		0.000	6.490	6.490	10.751	10.751	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	1		0.000	10.116	10.116	11.914	11.914	24.017	24.017	36.133	36.133	0.000	0.000	0.000
15	2		0.000	12.181	12.181	13.752	13.752	24.651	24.651	36.037	36.037	0.000	0.000	0.000
15	3		0.000	12.768	12.768	24.199	24.199	25.526	25.526	35.141	35.141	0.000	0.000	0.000
15	4		0.000	1.641	1.641	14.209	14.209	27.754	27.754	37.607	37.607	0.000	0.000	0.000
15	5		0.000	8.915	8.915	21.501	21.501	33.662	33.662	0.000	0.000	0.000	0.000	0.000
15	6		0.000	13.092	13.092	14.699	14.699	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	7		0.000	11.053	11.053	12.615	12.615	23.920	23.920	35.984	35.984	0.000	0.000	0.000
15	8		0.000	8.915	8.915	21.501	21.501	34.109	34.109	0.000	0.000	0.000	0.000	0.000
15	9		0.000	11.278	11.278	23.630	23.630	24.895	24.895	34.342	34.342	37.561	37.561	39.766
15	10		0.000	11.278	11.278	23.630	23.630	24.895	24.895	34.342	34.342	37.561	37.561	39.766
15	11		0.000	14.966	14.966	26.525	26.525	30.705	30.705	31.409	31.409	33.796	33.796	0.000
15	12		0.000	12.278	12.278	13.732	13.732	24.273	24.273	34.943	34.943	0.000	0.000	0.000
15	13		0.000	10.116	10.116	11.914	11.914	24.017	24.017	36.133	36.133	0.000	0.000	0.000
15	14		0.000	14.197	14.197	25.893	25.893	37.312	37.312	0.000	0.000	0.000	0.000	0.000
15	15		0.000	11.278	11.278	23.630	23.630	24.895	24.895	34.342	34.342	37.561	37.561	39.766

Assembly Parameters - Palisades Plant
Attachment to VSC-03.3605

		Asy Cyc:	1		2		3		4		5		6	
15	16		0.000	14.018	14.018	25.375	25.375	36.570	36.570	37.017	37.017	38.759	38.759	0.000
15	17		0.000	1.641	1.641	14.209	14.209	27.754	27.754	37.607	37.607	0.000	0.000	0.000
15	18		0.000	1.551	1.551	13.615	13.615	26.579	26.579	33.674	33.674	0.000	0.000	0.000
15	19		0.000	12.927	12.927	26.164	26.164	35.078	35.078	0.000	0.000	0.000	0.000	0.000
15	20		0.000	10.106	10.106	24.598	24.598	34.143	34.143	37.625	37.625	0.000	0.000	0.000
15	21		0.000	14.966	14.966	26.525	26.525	30.705	30.705	31.409	31.409	33.893	33.893	0.000
15	22		0.000	10.733	10.733	12.345	12.345	23.629	23.629	35.748	35.748	0.000	0.000	0.000
15	23		0.000	10.733	10.733	12.345	12.345	23.629	23.629	35.748	35.748	0.000	0.000	0.000
15	24		0.000	11.053	11.053	12.615	12.615	23.920	23.920	35.984	35.984	0.000	0.000	0.000
16	1		0.000	10.116	10.116	11.914	11.914	24.017	24.017	36.133	36.133	0.000	0.000	0.000
16	2		0.000	12.181	12.181	13.752	13.752	24.651	24.651	36.037	36.037	0.000	0.000	0.000
16	3		0.000	12.768	12.768	24.199	24.199	25.526	25.526	35.141	35.141	0.000	0.000	0.000
16	4		0.000	1.641	1.641	14.209	14.209	27.754	27.754	37.607	37.607	0.000	0.000	0.000
16	5		0.000	8.915	8.915	21.501	21.501	33.662	33.662	0.000	0.000	0.000	0.000	0.000
16	6		0.000	12.826	12.826	13.873	13.873	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	7		0.000	12.278	12.278	13.732	13.732	24.273	24.273	34.943	34.943	0.000	0.000	0.000
16	8		0.000	8.915	8.915	21.501	21.501	34.109	34.109	0.000	0.000	0.000	0.000	0.000
16	9		0.000	14.018	14.018	25.375	25.375	36.570	36.570	37.017	37.017	38.765	38.765	0.000
16	10		0.000	14.966	14.966	26.525	26.525	30.446	30.446	31.063	31.063	33.335	33.335	0.000
16	11		0.000	10.897	10.897	22.468	22.468	33.959	33.959	0.000	0.000	0.000	0.000	0.000
16	12		0.000	10.483	10.483	12.231	12.231	23.998	23.998	35.932	35.932	0.000	0.000	0.000
16	13		0.000	11.053	11.053	12.615	12.615	23.920	23.920	35.984	35.984	0.000	0.000	0.000
16	14		0.000	14.197	14.197	25.893	25.893	37.312	37.312	0.000	0.000	0.000	0.000	0.000
16	15		0.000	11.278	11.278	23.630	23.630	24.895	24.895	34.342	34.342	37.561	37.561	39.364
16	16		0.000	13.218	13.218	24.715	24.715	26.011	26.011	35.116	35.116	36.690	36.690	39.273
16	17		0.000	10.897	10.897	22.468	22.468	34.370	34.370	0.000	0.000	0.000	0.000	0.000
16	18		0.000	1.551	1.551	13.615	13.615	26.579	26.579	33.674	33.674	0.000	0.000	0.000
16	19		0.000	12.920	12.920	24.563	24.563	35.173	35.173	0.000	0.000	0.000	0.000	0.000
16	20		0.000	8.126	8.126	22.652	22.652	32.974	32.974	38.584	38.584	0.000	0.000	0.000
16	21		0.000	10.897	10.897	22.468	22.468	33.959	33.959	0.000	0.000	0.000	0.000	0.000
16	22		0.000	10.733	10.733	12.345	12.345	23.629	23.629	35.748	35.748	0.000	0.000	0.000
16	23		0.000	10.733	10.733	12.345	12.345	23.629	23.629	35.748	35.748	0.000	0.000	0.000
16	24		0.000	11.053	11.053	12.615	12.615	23.920	23.920	35.984	35.984	0.000	0.000	0.000
17	1		0.000	10.116	10.116	11.914	11.914	24.017	24.017	36.133	36.133	0.000	0.000	0.000
17	2		0.000	12.181	12.181	13.752	13.752	24.651	24.651	36.037	36.037	0.000	0.000	0.000
17	3		0.000	11.714	11.714	23.236	23.236	24.624	24.624	34.678	34.678	0.000	0.000	0.000
17	4		0.000	1.641	1.641	14.209	14.209	27.754	27.754	37.607	37.607	0.000	0.000	0.000
17	5		0.000	14.966	14.966	26.525	26.525	30.446	30.446	31.063	31.063	33.397	33.397	0.000
17	6		0.000	12.339	12.339	13.911	13.911	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	7		0.000	10.483	10.483	12.231	12.231	23.998	23.998	35.932	35.932	0.000	0.000	0.000
17	8		0.000	14.966	14.966	26.525	26.525	30.705	30.705	31.409	31.409	34.002	34.002	0.000

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		Asy Cyc:	1		2		3		4		5		6	
17	9		0.000	14.018	14.018	25.375	25.375	36.570	36.570	37.017	37.017	38.604	38.604	0.000
17	10		0.000	13.218	13.218	24.715	24.715	26.011	26.011	35.116	35.116	36.690	36.690	39.556
17	11		0.000	10.106	10.106	24.598	24.598	34.143	34.143	37.625	37.625	0.000	0.000	0.000
17	12		0.000	11.053	11.053	12.615	12.615	23.920	23.920	35.984	35.984	0.000	0.000	0.000
17	13		0.000	11.053	11.053	12.615	12.615	23.920	23.920	35.984	35.984	0.000	0.000	0.000
17	14		0.000	8.126	8.126	22.652	22.652	32.974	32.974	38.584	38.584	0.000	0.000	0.000
17	15		0.000	11.278	11.278	23.630	23.630	24.895	24.895	34.342	34.342	37.561	37.561	39.364
17	16		0.000	13.218	13.218	24.715	24.715	26.011	26.011	35.116	35.116	36.690	36.690	39.273
17	17		0.000	10.897	10.897	22.468	22.468	34.370	34.370	0.000	0.000	0.000	0.000	0.000
17	18		0.000	1.551	1.551	13.615	13.615	26.579	26.579	33.674	33.674	0.000	0.000	0.000
17	19		0.000	13.976	13.976	24.709	24.709	35.117	35.117	0.000	0.000	0.000	0.000	0.000
17	20		0.000	8.126	8.126	22.652	22.652	32.974	32.974	38.584	38.584	0.000	0.000	0.000
17	21		0.000	10.897	10.897	22.468	22.468	33.959	33.959	0.000	0.000	0.000	0.000	0.000
17	22		0.000	10.733	10.733	12.345	12.345	23.629	23.629	35.748	35.748	0.000	0.000	0.000
17	23		0.000	10.733	10.733	12.345	12.345	23.629	23.629	35.748	35.748	0.000	0.000	0.000
17	24		0.000	10.483	10.483	12.231	12.231	23.998	23.998	35.932	35.932	0.000	0.000	0.000
18	1		0.000	10.116	10.116	11.914	11.914	24.017	24.017	36.133	36.133	0.000	0.000	0.000
18	2		0.000	7.201	7.201	7.518	7.518	19.637	19.637	28.825	28.825	0.000	0.000	0.000
18	3		0.000	13.275	13.275	28.169	28.169	36.620	36.620	0.000	0.000	0.000	0.000	0.000
18	4		0.000	1.641	1.641	14.209	14.209	27.754	27.754	37.607	37.607	0.000	0.000	0.000
18	5		0.000	14.966	14.966	26.525	26.525	30.446	30.446	31.063	31.063	33.432	33.432	0.000
18	6		0.000	11.624	11.624	13.110	13.110	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	7		0.000	10.483	10.483	12.231	12.231	23.998	23.998	35.932	35.932	0.000	0.000	0.000
18	8		0.000	8.915	8.915	21.501	21.501	34.109	34.109	0.000	0.000	0.000	0.000	0.000
18	9		0.000	13.218	13.218	24.715	24.715	26.011	26.011	35.116	35.116	36.690	36.690	39.556
18	10		0.000	13.218	13.218	24.715	24.715	26.011	26.011	35.116	35.116	36.690	36.690	39.556
18	11		0.000	8.915	8.915	21.501	21.501	33.662	33.662	0.000	0.000	0.000	0.000	0.000
18	12		0.000	10.483	10.483	12.231	12.231	23.998	23.998	35.932	35.932	0.000	0.000	0.000
18	13		0.000	11.053	11.053	12.615	12.615	23.920	23.920	35.984	35.984	0.000	0.000	0.000
18	14		0.000	14.197	14.197	25.893	25.893	37.312	37.312	0.000	0.000	0.000	0.000	0.000
18	15		0.000	11.278	11.278	23.630	23.630	24.895	24.895	34.342	34.342	37.561	37.561	39.364
18	16		0.000	13.218	13.218	24.715	24.715	26.011	26.011	35.116	35.116	36.690	36.690	39.273
18	17		0.000	10.897	10.897	22.468	22.468	34.370	34.370	0.000	0.000	0.000	0.000	0.000
18	18		0.000	10.116	10.116	11.914	11.914	24.017	24.017	36.133	36.133	0.000	0.000	0.000
18	19		0.000	13.976	13.976	24.709	24.709	35.117	35.117	0.000	0.000	0.000	0.000	0.000
18	20		0.000	10.106	10.106	24.598	24.598	34.143	34.143	37.625	37.625	0.000	0.000	0.000
18	21		0.000	14.966	14.966	26.525	26.525	30.705	30.705	31.409	31.409	33.891	33.891	0.000
18	22		0.000	10.733	10.733	12.345	12.345	23.629	23.629	35.748	35.748	0.000	0.000	0.000
18	23		0.000	10.733	10.733	12.345	12.345	23.629	23.629	35.748	35.748	0.000	0.000	0.000
18	24		0.000	10.483	10.483	12.231	12.231	23.998	23.998	35.932	35.932	0.000	0.000	0.000
19	1		0.000	10.116	10.116	11.914	11.914	24.017	24.017	36.133	36.133	0.000	0.000	0.000

Assembly Parameters - Palisades Plant
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		Asy Cyc:	1		2		3		4		5		6	
19	2		0.000	7.201	7.201	7.518	7.518	19.637	19.637	28.825	28.825	0.000	0.000	0.000
19	3		0.000	11.212	11.212	25.794	25.794	35.205	35.205	0.000	0.000	0.000	0.000	0.000
19	4		0.000	1.641	1.641	14.209	14.209	27.754	27.754	37.607	37.607	0.000	0.000	0.000
19	5		0.000	14.966	14.966	26.525	26.525	30.446	30.446	31.063	31.063	33.411	33.411	0.000
19	6		0.000	11.651	11.651	12.990	12.990	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	7		0.000	12.278	12.278	13.732	13.732	24.273	24.273	34.943	34.943	0.000	0.000	0.000
19	8		0.000	8.915	8.915	21.501	21.501	34.109	34.109	0.000	0.000	0.000	0.000	0.000
19	9		0.000	13.218	13.218	24.715	24.715	26.011	26.011	35.116	35.116	36.690	36.690	39.556
19	10		0.000	11.278	11.278	23.630	23.630	24.895	24.895	34.342	34.342	37.561	37.561	39.364
19	11		0.000	8.915	8.915	21.501	21.501	33.662	33.662	0.000	0.000	0.000	0.000	0.000
19	12		0.000	10.483	10.483	12.231	12.231	23.998	23.998	35.932	35.932	0.000	0.000	0.000
19	13		0.000	11.053	11.053	12.615	12.615	23.920	23.920	35.984	35.984	0.000	0.000	0.000
19	14		0.000	14.197	14.197	25.893	25.893	37.312	37.312	0.000	0.000	0.000	0.000	0.000
19	15		0.000	13.218	13.218	24.715	24.715	26.011	26.011	35.116	35.116	36.690	36.690	39.273
19	16		0.000	8.126	8.126	22.652	22.652	32.974	32.974	38.584	38.584	0.000	0.000	0.000
19	17		0.000	10.897	10.897	22.468	22.468	34.370	34.370	0.000	0.000	0.000	0.000	0.000
19	18		0.000	10.116	10.116	11.914	11.914	24.017	24.017	36.133	36.133	0.000	0.000	0.000
19	19		0.000	13.976	13.976	24.709	24.709	35.117	35.117	0.000	0.000	0.000	0.000	0.000
19	20		0.000	1.641	1.641	14.209	14.209	27.754	27.754	37.607	37.607	0.000	0.000	0.000
19	21		0.000	10.897	10.897	22.468	22.468	33.959	33.959	0.000	0.000	0.000	0.000	0.000
19	22		0.000	12.768	12.768	24.199	24.199	25.526	25.526	35.141	35.141	0.000	0.000	0.000
19	23		0.000	12.278	12.278	13.732	13.732	24.273	24.273	34.943	34.943	0.000	0.000	0.000
19	24		0.000	10.483	10.483	12.231	12.231	23.998	23.998	35.932	35.932	0.000	0.000	0.000
0	0		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	0		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	0		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000