71-9001

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September 9, 2002

E&L-039-02

Mr. E. William Brach, Director
Licensing Section
Spent Fuel Project Office
Office of Nuclear Material Safety and Safeguards, NMSS
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Brach:

CONSOLIDATED SAFETY ANALYSIS REPORT FOR THE IF-300, CERTIFICATE OF COMPLIANCE 9001

Enclosed is our application for the revision to the Consolidated Safety Analysis Report (CSAR) for the IF-300, Certificate of Compliance No. 9001. We request that you approve the revision to the CSAR and revise the Certificate for IF-300 to reflect the following changes.

1. The maximum initial uranium content per Group III PWR assembly has been increased from 437 to 442 kg. The additional analyses demonstrating that this fuel type with additional uranium content meets regulatory requirements are contained in Appendix 9.3 to Appendix D, which is included in Volume IV of the CSAR. Appendix 9.3 is provided as a non-proprietary document.

2. Several pages in Volume IV Appendix D of the CSAR have been revised to reflect the addition of Appendix 9.3. Page D-3-1 contains proprietary information. Non-proprietary and proprietary versions of page D-3-1 are provided.

There are several attachments to this letter, including the CSAR revision pages themselves. The following is a discussion of the content and purpose of each attachment.

Attachment 1: A Revision Control sheet to the CSAR showing which pages have been changed from the current revision.

Attachment 2: The replacement pages for Volume IV. (Non-proprietary)

Attachment 3: Appendix 9.3 of Appendix D, Volume IV (Non-proprietary)

Attachment 4: Page D-3-1 (Proprietary)

NMSS01 PROP

We request completion of action on this request by December 2, 2002 to allow development of appropriate procedures and controls for use of the cask with the higher uranium content Group III PWR fuel from the H. B. Robinson Plant. The owner of the cask, CP&L, needs to ship Group III fuel from the H. B. Robinson Plant in early 2003 to maintain a prudent operating margin. This need stems from the U.S. Department of Energy's failure to begin taking spent fuel in 1998 as required by the Nuclear Waste Policy Act of 1982, as amended, and by its contracts with the nuclear utilities.

Should you or members of your staff have any questions about the application, please feel free to contact Mark Whittaker at (803) 758-1898.

Sincerely,

Anthony J. Lamie for

Patrick L. Paquin
General Manager – Engineering and Licensing

Attachments: As stated

E&L-039-02

ATTACHMENT 1

REVISION CONTROL SHEET

REVISION CONTROL SHEET

TITLE: Consolidated Safety Analysis Report for IF-300 Shipping Cask

DOCUMENT NO.: NEDO-10084

AFFECTED PAGE(S)	DOC. REV.	REMARKS
1-i	3	Last revision prepared by General Electric Company.
1-1 & 1-2	"	Incorporates all C of C 9001, Revision 29 references
2-i & 2-ii	"	From 2/8/84 through 5/10/85.
2-1 - 2-15	"	A vertical line on the right hand margin indicates a
3-i & 3-ii	"	Revision. "N" denotes new information while "E"
3-1 - 3-16	"	Denotes an editorial change.
4-i - 4-ii	"	
4-1 - 4-21	"	
5-i - 5-vi	"	
5-1 - 5-311	"	
6-i - 6-iv	"	
6-1 - 6-82	"	
7-i - 7-ii	"	
7-1 - 7-22	"	
8-i & 8-ii	"	
8-1 - 8-22	"	
9-i & 9-ii	"	
9-1 - 9-6	"	
10-i & 10-ii	"	
10-1 - 10-15	"	
A-i & A-ii	"	
V1-i - V1-iv	"	
V1-1 - V1-52	"	
V1-A-i/ii	"	
V1-A-1 -	"	
V1-A-3	"	
V1-B-i/ii	"	
V1-B-1 &	"	
V1-B-2	"	
V1-C-i/ii	"	
V1-C-1 -	"	
V1-C-8	"	PAGE 1 of 5

REVISION CONTROL SHEET

TITLE: Consolidated Safety Analysis Report for IF-300 Shipping Cask

DOCUMENT NO.: NEDO-10084

AFFECTED PAGE(S)	DOC. REV.	REMARKS
V1-D-i -	3	
V1-D-vi	"	
V1-D-1 -	"	
V1-D-132	"	
V1-E-i &		
V1-E-ii	"	
V1-E-1 -	"	
V1-E-34	"	
V2-i - V2-iv	"	
V2-1 - V2-64	"	
V3-i - V3-iv	"	
V3-1 - V3-32	"	
VI-i & VI-ii	"	
VI-1 - VI-6	"	
i - viii	4	First revision prepared by VECTRA Technologies, Inc.
1-1	"	Incorporates C of C 9001, Revision 29 references
2-1 & 2-2	"	From 7/26/90 through 4/25/99.
2-3 & 2-3a	"	A vertical line on the left hand margin indicates a
2-4 & 2-5	"	Revision.
2-8	"	
2-10 & 2-11	"	
2-14 & 2-15	"	
3-1 & 3-1a	"	
3-2a	"	
3-16	"	
4-1, 4-3, 4-5	"	
4-9 & 4-10	"	
5-1, 5-3, &	"	
5-5	"	
5-101 & 5-270	"	PAGE 2 of 5

REVISION CONTROL SHEET

TITLE: Consolidated Safety Analysis Report for IF-300 Shipping Cask

DOCUMENT NO.: NEDO-10084

AFFECTED PAGE(S)	DOC. REV.	REMARKS
6-1 & 6-1a	4	
6-2 & 6-2a	"	
6-33 & 6-35	"	
7-1 & 7-2	"	
8-1 & 8-3	"	
8-19 & 8-20	"	
9-1, 9-2, 9-6	"	
10-4	"	
A-i/ii	"	
A-iii -	"	
A-xiii	"	
A-1-1 -	"	
A-1-10	"	
A-2-1 -	"	
A-2-338	"	
A-3-1 -	"	
A-3-86	"	
A-4-1 - A-4-5	"	
A-5-1 -	"	
A-5-92	"	
A-6-1 -	"	
A-6-131	"	
A-7-1 & A-8-1	"	
A-9-1 -	"	
A-9-13	"	
B-i/ii	"	
B-iii & B-iv	"	
B-1 - B-55	"	
C-i/ii	"	
C-iii/iv	"	
C-1 - C-14	"	

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REVISION CONTROL SHEET

TITLE: Consolidated Safety Analysis Report for IF-300 Shipping Cask

DOCUMENT NO.: NEDO-10084

AFFECTED PAGE(S)	DOC. REV.	REMARKS
1-1 - 1-3	5	First revision prepared by CNS, Inc.
2-1 - 2-3a	"	Incorporates C of C 9001, Revision 34 references
2-10 - 2-12a	"	From 01/09/1998 through 11/09/2000.
2-14 & 2-15	"	A vertical line on the left hand margin indicates
3-1 & 3-1a	"	changed text. The date in the header reflects the
4-ii & 4-22	"	date of the submittal.
5-3 & 5-4	"	
6-1 - 6-2	"	
8-1 & 8-2	"	
9-1 -& 9-2	"	
9-5 & 9-6	"	
10-i - 10-ii	"	
10-1 - 10-15	"	
D-i - D-vii	"	
D-1-1 - D-1-2	"	
D-2-1 - D-2-3	"	
D-3-1- D-3-15	"	
D-4-1- D-4-16	"	
D-5-1- D-5-13	"	
D-6-1 -	"	
D-6-170	"	
D-7-1- D-7-11	"	
D-8-1 - D-8-3	"	
D-9-1- D-9-46	"	
		PAGE 4 of 5

REVISION CONTROL SHEET

TITLE: Consolidated Safety Analysis Report for IF-300 Shipping Cask

DOCUMENT NO.: NEDO-10084

AFFECTED PAGE(S)	DOC. REV.	HEADER DATE	REMARKS
1-1 - 1-2	5	August 2001	First revision prepared by Duratek, Inc. The document revision level is not changed since only a fraction of the SAR is changed. A vertical line in the margin indicates changed text. The date in the page header reflects the date of the change. The revision status of a particular page is noted by the revision number and header date.
2-10 - 2-11	"	"	
4-13	"	"	
6-79 - 6-80	"	"	
9-5 - 9-6	"	"	
10-i - 10-ii	"	"	
10-1 - 10-15	"	"	
E-i - E-v	"	January 2002	
E-1-1	"	"	
E-2-1 - E-2-3	"	"	
E-3-1 - E-3-9	"	"	
E-4-1 - E-4-26	"	"	
E-5-1 - E-5-34	"	"	
E-6-1 - E-6-3	"	"	
E-7-1 - E-7-2	"	"	
E-8-1 - E-8-453	"	"	
D-1-2 - D-1-2a	5	September 2002	Second revision prepared by Duratek, Inc. The document revision level is not changed since only a fraction of the SAR is changed. A vertical line in the margin indicates changed text. The date in the page header reflects the date of the change. The revision status of a particular page is noted by the revision number and header date.
D-2-1 - D-2-1a	"	"	
D-3-1	"	"	
D-4-1	"	"	
D-5-1 - D-5-1a	"	"	
D-6-5 - D-6-5a	"	"	
D-7-2 - D-7-2a	"	"	
D-9-47 - D-9-80	"	"	

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ATTACHMENT 2

REPLACEMENT PAGES
VOLUME IV

Appendix D-9.3 was added to address GIII PWR fuel assemblies with a maximum of 442 kg of uranium per assembly because it was discovered that some of the GIII PWR fuel had slightly greater uranium masses than the 437 kg originally analyzed. Appendix D-9.3 addresses the impact of the slight increase in uranium mass on the neutron and gamma source strengths, decay heat, releasable source terms during hypothetical accident conditions, and criticality safety of the IF-300 Package. It is concluded that all of the transportation requirements specified in 10 CFR 71, as well as the limits specified in the IF-300 C of C (C of C No. 9001) and the Consolidated Safety Analysis Report (CSAR 1995) are satisfied when shipping GIII PWR fuel assemblies with uranium masses up to 442 kg/assembly as long as the other loading restrictions listed in Table D-1.1 are satisfied.

Table D-1.1

Characteristics of Group III Assemblies

Parameter	PWR Fuel	BWR Fuel
Fuel Type	15x15 SPC PWR for Westinghouse Class 15x15 Reactors	GE-7, 8, 9, 10 & 13 BWR Fuel for General Electric BWR/4 Plant Design
Uranium Weight	~~437~~ 442 kg/assembly[d]	187 kg/assembly
Number of Assemblies	6[a]	17 channeled
Maximum Assembly Average Burnup	45 GWD/MTU	45 GWD/MTU
Maximum Lattice Average Enrichment[b]	4.25 wt% ^{235}U	4.25 wt% ^{235}U
Minimum Blanket Length[c]	6 inches	6 inches
Minimum Cooling Time	5 years	4 years

[a] The center location in the PWR basket must be left empty. If an assembly is loaded in the center PWR basket location and a peripheral location is instead left empty, the cask will not meet the criticality safety criteria with 6 assemblies at 4.25 wt% ^{235}U.

[b] The maximum lattice average enrichment is defined as the maximum planar average enrichment of any axial plane from the bottom to the top of the fuel assembly. Although some individual fuel rod enrichments may exceed this enrichment, the average enrichment for

every axial slice across the fuel assembly must not exceed the maximum lattice average enrichment.

[c] The minimum length of natural UO_2 fuel above and below the enriched portion of the active fuel.

[c] Appendix D-9.3 contains the evaluation for an increase in the uranium mass from 437 kg/assembly to 442 kg/assembly.

A plug was designed for the PWR fuel basket to prevent inadvertent loading of the center basket location. The plug has an outer lip that rests on the top of the basket when the plug is inserted into the basket. The plug extends above the basket 3.625 in and down into the basket approximately 8 in to prevent it from accidentally coming out during fuel loading or transport. The bottom of the plug is approximately 7 in above the top of the active fuel and the plug itself adds only a small amount of steel in a region of low importance from a criticality standpoint. Also, because the plug is located above the empty center basket location, the reactivity effect due to reflection of neutrons back into the fuel is negligible.

D-2.0 ANALYSIS METHODOLOGY

The approach used in this appendix to address the effect of the change on the pre-1995 IF-300 certification is described in this section. Appendix D-9.3 contains the evaluation for an increase in the uranium mass from 437 kg/assembly to 442 kg/assembly for the GIII PWR fuel. Appendix D-9.3 addresses the safety implications of the increased uranium mass for each of the assessments described in Sections 2.1 through 2.5.

D-2.1 Structural Assessment

The requested change deals with increasing the permissible burnup and enrichment of fuel to be shipped in the IF-300 package for specific types of PWR and BWR fuel, which are designated as Group III fuel assemblies. The Group III fuel assemblies have outer dimension envelopes that are compatible with the Group I and II fuel designs, and fuel assembly weights that are bounded by the Group I and II fuel designs already permitted under the current IF-300 Cask C of C (C of C No. 9001). The total weight of a PWR Group III fuel assembly is 653.2 kg, and the maximum assembly weight for the BWR Group III fuel designs is 301.2 kg (GE-7). This results in a total fuel assembly loading of 3,920 kg (6 x 653.2 kg) for the PWR cask and 5,120 kg (17 x 301.2 kg) for the BWR cask. This is below the structural evaluation design basis assembly loading of 4,920 kg for the PWR cask and 5,205 kg for the BWR Cask with the channeled fuel assembly basket. The PWR cask analysis basis fuel loading of 4,920 kg was obtained by subtracting the PWR basket weight (2,050 kg from p. 5-100) from the maximum PWR basket weight with fuel (6,970 kg from p. 5-99). The BWR cask analysis basis fuel loading of 5,205 kg was obtained from Table A-2.2-1 (p. A-2-8) for the channeled BWR fuel basket. Therefore, there is no change in the structural aspects of the contents to be shipped.

Furthermore, since Section 4.0 indicates that the number of moles of residual gas available for release in the cask cavity and the total decay heat load will remain within the pre-1994 licensed limit of 0.5 moles and 40,000 Btu/h, respectively, no change in the internal pressure will occur. Therefore, the proposed change has no effect on the structural analysis of the cask upon which the current C of C (C of C No. 9001) is based.

D-3.0 NEUTRON AND GAMMA SOURCE STRENGTH AND DECAY HEAT CALCUATION

This section determines the neutron and gamma source strengths and the decay heat for the higher burnup and higher enrichment fuel assemblies described in Table D-1.1. The calculation of the neutron and gamma source strengths are performed using ORIGEN2 (Savino 1999). ORIGEN2 is a computer code which calculates the buildup and decay of radioactive materials. ORIGEN2 code was developed by the Oak Ridge National Laboratory and is distributed through the Radiation Shielding Information Computational Center.

Sections D-3.1 and D-3.2 describe the ORIGEN2 models for the GIII PWR and BWR fuel assemblies, respectively. Sections D-3.3 and D-3.4 describe the results of the ORIGEN2 calculations for the GIII PWR and BWR fuel assemblies, respectively. Sections D-3.1 and D-3.3 are based on PWR fuel with a uranium mass of 437 kg/assembly. Appendix D-9.3 contains ORIGEN2 models for the GIII PWR fuel with a uranium mass of 442 kg/assembly.

D-3.1 ORIGEN2 Input File Preparation for Group III PWR Fuel

The GIII PWR fuel assembly is assumed to consist of four axial regions for the source term calculation: the active fuel region, the gas plenum region, the upper tie plate region, and the lower tie plate region.

The GIII PWR fuel assembly consists of 204 fueled rods, 20 control rod guide tubes, and one instrument tube. The fuel rod cladding material is Zircaloy-4. The cladding extends into the top plenum zone and the bottom end fitting zone. The total rod length is [redacted] in out of which 144 in is in the active fuel zone, [redacted] in is in the top plenum zone, and [redacted] in is in the lower tie plate zone. The Zircaloy-4 weight due to cladding in various regions of the fuel assembly is assumed to be proportional to the cladding lengths in these regions. The component weights were taken from Kunita (1998) and are described below.

The highlighted data is proprietary information to Siemens Power Corporation

D-4.0 DETERMINATION OF ACTIVATION PRODUCTS AND CONTAINMENT EVALUATION

The generation of the activation product and containment evaluation source terms is included in this section. Sections D-4.1 and D-4.2 contain the results for the GIII PWR fuel and the GIII BWR fuel, respectively. Appendix D-9.3 contains the results for GIII PWR fuel with a uranium mass of 442 kg/assembly.

D-4.1 Group III PWR Fuel

D-4.1.1 Upper Nozzle Hardware Activation Product Source

Activation analysis is performed to determine the impact of higher burnup on the ^{60}Co content of the upper nozzle of the GIII PWR fuel assemblies with a burnup of 50 GWD/MTU and a cooling time of 5 years. This evaluation conservatively uses a maximum burnup of 50 GWD/MTU for the PWR fuel, which bounds the results for 45 GWD/MTU.

An activation analysis based on a unit mass (one kg) of Cobalt for a burnup of 35 GWD/MTU is contained in Appendix D-9.1, ORIGEN2 run CO265US. Also the activation analysis based on a unit mass (one kg) of Cobalt for a burnup of 50 GWD/MTU is contained in Appendix D-9.1, ORIGEN2 run CO345UE. A comparison of the results is included in Section D-7.

D-4.1.2 Containment Evaluation Source Terms

The increase in the fuel assembly enrichment limit from 4 wt% ^{235}U to 4.25 wt% ^{235}U will impact the releasable source terms from the IF-300 Package. NUREG/CR-6487 (NRC 1996) identifies 3 sources which should be considered when determining the releasable source term for packages designed to transport irradiated fuel rods: 1) crud spallation from fuel rods, 2) release of fines from cladding breaches, and 3) source activity from gases and volatiles released due to cladding breaches. Each of these sources is addressed below. The fission gas product moles calculation is included in Section D-4.1.2.4.

D-5.0 COMPARISON WITH IF-300 PACKAGE C OF C

The key evaluation parameters affected by the increased burnup and enrichment are:

- Decay Heat
- Gamma Shielding
- Neutron Shielding
- Hardware Activation
- Containment Evaluation Source Terms
- Fission Gas Product Moles Source Term
- Criticality

Section D-5.1 contains a comparison of the key evaluation parameters for the existing analysis-basis and those for the IF-300 cask loaded with six higher enrichment GIII PWR fuel assemblies from Robinson. Note that the evaluation parameters for the PWR fuel were generated for a burnup of 50 GWD/MTU and a 5 year cooling time, which bounds the values for 45 GWD/MTU and a 5 year cooling time. Appendix D-9.3 contains the comparison for the GIII PWR fuel with a uranium mass of 442 kg/assembly. Section D-5.2 contains a comparison of the key evaluation parameters for the existing analysis-basis and those for the IF-300 cask loaded with seventeen higher burnup and enrichment GIII BWR fuel assemblies from Brunswick. The criticality safety aspects of the evaluation are contained in Section 6.0.

D-5.1 Results for Group III PWR Fuel

D-5.1.1 Decay Heat

The IF-300 shipping cask C of C limit is 40,000 Btu/h, which corresponds to 5,714 Btu/h/FA for the analysis-basis fuel assembly heat loading for the cask loaded with seven assemblies. The maximum decay heat from the Group III PWR fuel assemblies with a burnup of 50 GWD/MTU, a minimum enrichment of 3.45 wt% ^{235}U, and a cooling time of 5 years is 4,768 Btu/h per assembly, or a total of 28,608 Btu/h for a cask loading of six fuel assemblies. Therefore, the total cask heat loading and the fuel assembly heat loading for SPC PWR fuel with a burnup of 50 GWD/MTU and a cooling time of

5 years are well within the IF-300 shipping cask analysis-basis values. The uranium inventory of the

D-6.1.2 Summary of Criticality Evaluation Results

Table D-6.1-2 contains a summary of the key criticality evaluation results for the IF-300 Cask. Appendix D-9.3 addresses the impact on the criticality evaluation of an increase in the uranium loading from 437 to 442 kg/assembly for GIII PWR fuel.

Table D-6.1-2

Summary Table of Criticality Evaluations

	6 Group III PWR Fuel Assemblies with 4.25 wt% ^{235}U	17 Group III BWR Fuel Assemblies with 4.25 wt% ^{235}U
Normal Conditions of Transport (NCT)		
Number of Undamaged Packages	∞	∞
Single Unit Maximum k_{tot}[a]	0.34574	0.34566
Infinite Array Maximum k_{tot}[a]	0.38123	0.37208
k_{eff} Limit	0.95	0.95
Hypothetical Accident Conditions (HAC)		
Single Unit Maximum k_{tot}[a]	0.94427	0.92846
Infinite Array Maximum k_{tot}[a]	0.94636	0.93625
k_{eff} Limit	0.95	0.95

[a] $k_{tot} = k_{eff}$ including bias and uncertainties (see Sections D-6.4-3 and D-6.7).

D-6.1.3 Transport Index

The maximum calculated k_{tot} is less than 0.95 for infinite arrays of IF-300 casks under Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC) when the casks are loaded with six 4.25 wt% ^{235}U GIII PWR fuel assemblies with the center basket location empty, or with seventeen 4.25 wt% ^{235}U GIII BWR fuel assemblies. Therefore, a criticality Transport Index of zero (0) is justified.

D-6.2 Spent Nuclear Fuel Contents

Prior to 1991, the IF-300 Cask was licensed for transport of up to seven PWR or eighteen unchanneled BWR irradiated fuel assemblies. The enrichment limit was 4 wt% ^{235}U for both the PWR and BWR fuel. The

Appendix D-9.3 contains the evaluation for an increase in the uranium loading for the GIII PWR fuel assemblies from 437 to 442 kg/assembly. It was discovered that some of the GIII PWR fuel had slightly greater uranium masses than the 437 kg originally analyzed.

Table D-7.1-1

Comparison of Key Evaluation Parameters for Group III 15x15 PWR Fuel With an Exposure of 50 GWD/MTU[a] and a 5-Year Cooling Time and the Analysis-Basis Values

PARAMETER[b]	ANALYSIS BASIS	SIX GROUP III PWR FAS	MARGIN, %
NEUTRON SOURCE (NEUTRON/S/CASK)	1.87E+09	4.08E+09	-218
GAMMA SOURCE (GAMMA/S/CASK)	7.90E+16	5.54E+16	30
DECAY HEAT (BTU/H/CASK)	40,000	28,608	28
RELEASABLE ^{85}KR (Ci/CASK)	13,086	8,904	32
TOTAL RELEASABLE RESIDUAL FISSION PRODUCT MOLES	0.5	0.32	36
	(Ci OF ^{60}CO/KG COBALT)	(Ci OF ^{60}CO/KG COBALT)	
HARDWARE ACTIVATION	1.42E+04	1.33E+04	6

[a] This evaluation conservatively uses a maximum burnup of 50 GWD/MTU for the PWR fuel, which bounds the results for 45 GWD/MTU.

[b] Section D-5.1 addresses additional containment evaluation parameters (i.e., crud spallation, total gases and volatiles, and releases from fuel fines) and qualitatively demonstrates that the GIII PWR fuel is bounded by the analysis basis PWR fuel for these parameters.

D-7.1-1 Estimates of NCT and HAC Dose Rates for the IF-300 PWR Cask

NCT Dose Rates at the IF-300 PWR Cask Surface

The neutron and gamma dose rates at the surface of the IF-300 cask are estimated using the method described in Appendix B. This method involves calculating the neutron and gamma dose rates by scaling the dose rates for the analysis basis BWR fuel loading by the ratio of the neutron (or gamma) source terms for the PWR fuel to the neutron (or gamma) source terms for the analysis basis BWR fuel. The dose rates used are from the 17 element channeled BWR fuel basket (CSAR 1995) shielding evaluation (Table A-5.4-5, p. A-5-35) since

the CSAR does not report the total neutron and gamma dose rates with dry cask inner cavity PWR fuel shipments. Section D-5.1.2 provides the justification for use of the dose rates from the BWR fuel basket. From Section D-5.1.2, the analysis-basis assembly neutron source term is exceeded by a factor of 2.55

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ATTACHMENT 3

APPENDIX 9.3

D-9.3 Appendix C - Justification for Increase in Uranium Loading from 437 to 442 kg/assembly for the GIII PWR Fuel

This appendix addresses GIII PWR fuel assemblies with a maximum of 442 kg of uranium per assembly because it was discovered that some of the GIII PWR fuel had slightly greater uranium masses than the 437 kg originally analyzed. It addresses the impact of the slight increase in uranium mass on the structural, thermal, containment, shielding, and criticality assessments for the IF-300 Package. It is concluded that all of the transportation requirements specified in 10 CFR 71, as well as the limits specified in the IF-300 C of C (C of C No. 9001) and the Consolidated Safety Analysis Report (CSAR 1995) are satisfied when shipping GIII PWR fuel assemblies with uranium masses up to 442 kg/assembly as long as the other loading restrictions listed in Table D-1.1 are satisfied. Each of the assessments are addressed separately below.

D-9.3.1 Structural Assessment

An increase in uranium weight from 437 to 442 kg/assembly results in an overall weight of 658.2 kg for a GIII PWR fuel assembly, which is equal to a total fuel assembly loading of 3,949 kg (6 x 658.2 kg) for the PWR cask. This is below the structural evaluation design basis assembly loading of 4,920 kg for the PWR cask (see Section D-2.1). Therefore, there is no change in the structural aspects of the contents to be shipped.

D-9.3.2 Thermal Assessment

This section determines the decay heat for the GIII PWR fuel with a uranium loading of 442 kg/assembly. The calculation of the decay heat is performed using ORIGEN2 (Savino 1999). Section D-3.1 describes the ORIGEN2 models for the GIII PWR with a uranium loading of 437 kg/assembly for both the minimum initial enrichment (3.45 wt% U-235) and the maximum initial (4.25 wt% U-235) enrichment fuel. The only change made to the

ORIGEN2 models for this evaluation was to increase the uranium loading to 442 kg/assembly, which is approximately a 1.1% increase. These ORIGEN2 models were also used to determine the releasable source terms for the containment assessment in Appendix D-9.3.3, and the neutron and gamma source terms for the shielding assessment in Appendix D-9.3.4. The ORIGEN2 input files for both cases are included in Appendix D-9.4. ORIGEN2 was run on Duratek Federal Services Northwest Computer Serial Number 0022738297.

The increase in uranium results in an increase in the decay heat from 1,397 kW (4,768 Btu/h) to 1,414 kW (4,826 Btu/h) per assembly after a 5 year cooling time for the GIII PWR fuel assemblies with a minimum initial enrichment of 3.45 wt% ^{235}U, which bounds that for the maximum initial enrichment of 4.25 wt% ^{235}U. This corresponds to a total cask inner cavity heat load of:

Total Cask Inner Cavity Heat Load = 6 FA/Cask x 4,826 Btu/h/FA
= 28,956 Btu/h

It is concluded that the thermal analysis, which calculated temperatures and pressures in the IF-300 cask for a 40,000 Btu/h heat load, will bound the GIII PWR fuel with a minimum cooling time of 5 years and a maximum uranium loading of 442 kg/assembly.

D-9.3.3 Containment Assessment

This section addresses the impact of the change in the uranium mass loading for the GIII PWR fuel from 437 to 442 kg/assembly on the containment evaluation. The same ORIGEN2 models that were used to determine the decay heat in Section D-9.3.2 were used to calculate the releasable source terms under accident conditions for the containment assessment. NUREG/CR-6487 (NRC 1996) identifies 3 sources which should be considered

when determining the releasable source term for packages designed to transport irradiated fuel rods: 1) crud spallation from fuel rods, 2) release of fines from cladding breaches, and 3) source activity from gases and volatiles released due to cladding breaches. The following sections demonstrate that the analysis basis PWR fuel assembly source terms for each of these sources bound the source terms for the GIII PWR fuel with a uranium loading of 442 kg/assembly.

D-9.3.3.1 Crud Spallation from Fuel Rods

Following the methodology in NUREG/CR-6487 (NRC 1996) the crud spallation fraction (f_C) is a function of the surface area of the fuel rod and is independent of the uranium mass loading. Because the increased uranium loading does not affect the surface area of the fuel rod, the conclusion reached in Section D-4.1.2.1 for the GIII PWR fuel remains valid, i.e., that the crud spallation source term for the GIII PWR fuel is bounded by that for the analysis basis PWR fuel.

D-9.3.3.2 Source Activity due to Releases of Fines from Cladding Breaches

Section D-4.1.2.2 states that the only fuel-dependent parameters in the equation for the activity concentration inside the containment vessel as a result of fines released form cladding breaches are the total cask fuel mass and the specific activity of the fines (Ci/g).

Table D-9.3-1 lists the ORIGEN2 radioisotope inventory from Table D-4.1-2-2 for a single analysis basis PWR assembly with a 2 year cooling time and the inventory for a single GIII PWR assembly after a 5 year cooling time using the ORIGEN2 model developed in Section D-9.3.1 for a uranium loading of 442 kg/assembly. Note that the 3.45 wt% fuel inventory bounds that for the 4.25 wt% fuel. These results indicate that the analysis basis PWR fuel has a specific activity of 1.35 Ci/g (6.30E5 Ci/465,000 g) for a 2 year cooling time, and the GIII PWR fuel has a

specific activity of 0.82 Ci/g (3.64E5 Ci/442,000 g) for a 5 year cooling time.

The total cask fuel mass for a cask loading of 7 analysis basis GI 15x15 PWR fuel assemblies is 3,255 kg (7 x 465 kg) (see Section D-4.1.2.2) which is much greater than that for a cask loading of 2,652 kg (6 x 442 kg) for 6 GIII PWR fuel assemblies. Because both the specific activity and total cask fuel mass for the GIII PWR fuel are much lower than that for the analysis basis PWR fuel, the activity of the fuel fines for the analysis basis PWR fuel bounds that for the GIII PWR fuel.

D-9.3.3.3 <u>Source Activity from Gases and Volatiles Released due to Cladding Breaches</u>

The radioisotope inventory of the gases and volatiles from ORIGEN2 is listed in Table D-9.3-2 for the analysis basis fuel and for the GIII PWR fuel with a uranium loading of 442 kg/assembly. The values for the analysis basis fuel after a 2 year cooling time were taken from Table D-4.1-2-3. This comparison indicates that the GIII PWR fuel cooled 5 years has a lower inventory of gases and volatiles than the analysis basis PWR fuel assembly cooled 2 years. Therefore, the activity of the gases and volatiles from the analysis basis PWR fuel bounds that for the GIII PWR fuel with a uranium loading of 442 kg/assembly. Note that the radioisotope inventory for the gases from the 4.25% GIII PWR fuel bounds that for the 3.45% fuel, and the radioisotope inventory for the volatiles from the 3.45% GIII PWR fuel bounds that for the 4.25% fuel.

Table D-9.3-1

Radioisotope Inventories of Analysis-Basis and Group III PWR Fuel to Determine the Specific Activity of the Fuel
(2 sheets total)

Analysis Basis PWR - 3.5%, 2 yr cooled		Group III PWR - 3.45%, 5 yr cooled	
Isotope	Ci[a]	Isotope	Ci[a]
H 3	3.46E+02	H 3	3.77E+02
FE55	2.72E+00	MN54	2.48E+00
CO60	5.79E+01	FE55	2.55E+02
ZN65	7.61E+00	CO60	9.90E+02
KR85	5.34E+03[b]	NI63	6.55E+01
SR89	1.93E+01	KR85	4.02E+03
SR90	3.49E+04	SR90	3.85E+04
Y 90	3.49E+04	Y 90	3.85E+04
Y 91	9.93E+01	ZR93	1.13E+00
ZR95	2.91E+02	TC99	8.14E+00
NB95	6.68E+02	RU106	1.15E+04
NB95M	2.16E+00	RH106	1.15E+04
RU103	2.02E+00	AG110M	2.74E+01
RH103M	1.83E+00	CD113M	3.97E+01
RU106	6.36E+04	SN119M	2.74E+01
RH106	6.36E+04	SB125	3.15E+03
AG110	3.33E+00	TE125M	7.68E+02
AG110M	2.50E+02	CS134	2.82E+04
SN123	3.41E+01	CS137	6.11E+04
SB125	4.01E+03	BA137M	5.78E+04
TE125M	9.78E+02	CE144	6.27E+03
TE127	6.70E+01	PR144	6.27E+03
TE127M	6.84E+01	PR144M	7.52E+01
CS134	4.07E+04	PM147	1.43E+04
CS137	4.87E+04	SM151	2.36E+02
BA137M	4.61E+04	EU152	2.73E+00
CE144	9.19E+04	EU154	5.87E+03
PR144	9.19E+04	EU155	2.97E+03
PR144M	1.10E+03	U 237	1.51E+00
PM147	3.78E+04	NP239	2.52E+01
SM151	1.77E+02	PU238	3.29E+03
EU154	3.85E+03	PU239	1.93E+02
EU155	2.17E+03	PU240	3.45E+02
U 237	1.28E+00	PU241	6.16E+04
NP239	8.50E+00	PU242	1.48E+00
PU238	1.31E+03	AM241	6.44E+02
PU239	1.55E+02	AM242M	1.18E+01
PU240	2.35E+02	AM242	1.17E+01
PU241	5.23E+04	AM243	2.52E+01
AM241	2.33E+02	CM242	2.58E+01
AM242M	6.83E+00	CM243	2.48E+01

Analysis Basis PWR - 3.5%, 2 yr cooled		Group III PWR - 3.45%, 5 yr cooled	
Isotope	Ci[a]	Isotope	Ci[a]
AM242	6.80E+00	CM244	4.86E+03
AM243	8.50E+00	Total	3.64E+05
CM242	8.82E+02	Specific Activity, Ci/g	0.82[c]
CM243	8.60E+00		
CM244	9.54E+02		
Total	6.30E+05		
Specific Activity, Ci/g	1.35[c]		

[a] Note that isotopes with activities less than 1 Ci are not included since they have a negligible impact on the total.

[b] The analysis basis Kr-85 inventory available for release from the cask during hypothetical accident conditions is a total of 13,086 Ci. This is equivalent to a Kr-85 fuel assembly inventory of 5.34E+03 Ci (13,086 Ci/0.35/7) for the analysis basis loading of 7 PWR assemblies per cask. A factor of 0.35 is applied to the rod inventory to determine the amount of Kr-85 that is available for release.

[c] Specific activity is based on a U mass loading of 465 kg for the analysis basis PWR fuel and 442 kg for the SPC PWR fuel.

Table D-9.3-2

Comparison of Analysis-Basis PWR Fuel and Group III PWR Fuel Gases and Volatiles

Isotope	Gases, Ci		Isotope	Volatiles, Ci	
	AB	Group III[a]		AB	Group III[b]
H 3	3.46E+02	3.63E+02	SR89	1.93E+01	4.42E-06
KR85	5.34E+03[c]	4.29E+03	SR90	3.49E+04	3.85E+04
XE133	1.47E-36	0.00E+00	RU103	2.02E+00	8.64E-09
Total	5.69E+03	4.65E+03	RU106	6.36E+04	1.15E+04
			CS134	4.07E+04	2.82E+04
			CS136	4.49E-13	4.19E-38
			CS137	4.87E+04	6.11E+04
			Total	1.88E+05	1.39E+05

[a] The 4.25% GIII PWR fuel has the largest inventory of gases.

[b] The 3.45% GIII PWR fuel has the largest inventory of volatiles.

[c] The analysis basis Kr-85 inventory available for release from the cask during hypothetical accident conditions is a total of 13,086 Ci. This is equivalent to a Kr-85 fuel assembly inventory of 5.34E+03 Ci (13,086 Ci/0.35/7) for the analysis basis loading of 7 PWR assemblies per cask. A factor of 0.35 is applied to the rod inventory to determine the amount of Kr-85 that is available for release.

D-9.3.4 Shielding Assessment

The same ORIGEN2 models that were used to determine the decay heat in Section D-9.3.2 were used to calculate the neutron and gamma source terms for the shielding assessment. Bounding neutron and gamma source terms occur for the minimum initial enrichment of 3.45 wt% U-235.

D-9.3.4.1 Neutron Source Strength Calculation

The total neutron emission rate from ORIGEN2 for GIII PWR fuel with a uranium loading of 442 kg/assembly is 6.88E+08 neutrons/sec/assembly for 3.45 wt% U-235 at a burnup of 50 GWD/MTU and a decay time of 5 years. Therefore, the total neutron source emission rate for the cask loaded with 6 GIII PWR fuel assemblies is:

Total Neutron Emission Rate = 6.88E+08 n/s/FA x 6 FA/cask
= 4.13E+09 n/s/cask

D-9.3.4.2 Gamma Source Strength Calculation

The total gamma emission rate from ORIGEN2 for the bounding case is 9.35E+15 gamma/sec/assembly. Therefore, the total gamma emission rate for the cask loaded with 6 GIII PWR fuel assemblies is:

Total Gamma Emission Rate = 9.35E+15 γ/s/FA x 6 FA/cask
= 5.61E+16 γ/s/cask

D-9.3.4.3 Resulting Total Dose Rates

Tables D-9.3-3 and D-9.3-6 summarize the resulting dose rates for the increased uranium loading along with those for the current licensed design as listed in Tables D-7.1-2 through D-7.1-5. The dose rates shown for the GIII PWR Fuel with a uranium loading of 442 kg/assembly are calculated using the methodology described in Section D-7.1. Although the neutron dose rates

are higher than the analysis-basis values, the total neutron plus gamma dose rates are below the 10 CFR 71 limits and satisfy the limits stated in the existing C of C.

Table D-9.3-3

IF-300 PWR Cask NCT Dose Rates on the Cask Surface

Location	CURRENT LICENSED DESIGN (CSAR 1995), mrem/h			SIX GROUP III PWR ASSEMBLIES WITH 442 KG URANIUM LOADING, mrem/h		
	Neutron	Gamma	Total n+g	Neutron[1]	Gamma[2]	Total n+g
Side(cask midplane), R_o	3.03	9.77	12.8	7.82	8.11	15.93
Side(top nozzle), R'_0	44.93	674.6	719.53	115.92	559.92	675.84
Top, T_0	44.93	13.7	58.63	115.92	11.37	127.29
Bottom, B_0	74.11	3.96	78.07	191.20	3.29	194.49
Dose Rate Limit			1000			1000

[1] Estimated neutron dose rate was calculated by multiplying the CSAR neutron dose rate from Table A-5.4-5 times the ratio of the GIII assembly neutron source term to the analysis basis assembly neutron source term (from Section D-9.3.4.1, 2.58 = 6.88E8/2.67E8 n/s).

[2] Estimated gamma dose rate was calculated by multiplying the CSAR gamma dose rate from Table A-5.4-5 times the ratio of the assembly gamma source term for GIII PWR assemblies to that for the analysis basis fuel (from Section D-9.3.4.2, 0.83 = 9.35E15/1.13E16 g/s).

Table D-9.3-4

IF-300 PWR Cask Estimated NCT Dose Rates at the Aluminum Enclosure and the Edge of the Conveyance Bed

Location	mrem/h
Side(cask midplane)	7.2[1]
Side(top nozzle)	148[1]
Top	<127.3[2]
Bottom	<194.5[2]
Dose Rate Limit	200

[1] Estimated dose rate at the top of the aluminum enclosure adjacent to the cask midplane or top nozzle. See Section D-7.1-1 for the calculational methodology.

[2] Estimated dose rate at the edge of the conveyance bed for the top and bottom of the cask. See Section D-7.1-1 for the calculational methodology.

Table D-9.3-5

IF-300 PWR Cask NCT Dose Rates at 2 m from the Vehicle Surface

Location	CURRENT LICENSED DESIGN (CSAR 1995), mrem/h			SIX GROUP III PWR ASSEMBLIES WITH 442 KG URANIUM LOADING mrem/h		
	Neutron	Gamma	Total n+g	Neutron[1]	Gamma[2]	Total n+g
Side(cask midplane), R_0	0.71	2.33	3.04	1.83	1.93	3.77
Side(top nozzle), R'_0	0.92	8.5	9.42	2.37	7.06	9.43
Top, T_0	1.8	2.82	4.62	4.64	2.34	6.98
Bottom, B_0	2.97	0.95	3.92	7.66	0.79	8.45
Dose Rate Limit			10			10

[1] Estimated neutron dose rate was calculated by multiplying the CSAR neutron dose rate from Table A-5.4-5 times the ratio of the GIII assembly neutron source term to the analysis basis assembly neutron source term (from Section D-9.3.4.1, 2.58 = 6.88E8/2.67E8 n/s)

[2] Estimated gamma dose rate was calculated by multiplying the CSAR gamma dose rate from Table A-5.4-5 times the ratio of the assembly gamma source term for GIII assemblies to that for the analysis basis fuel (from Section D-9.3.4.2, 0.83 = 9.35E15/1.13E16 n/s).

Table D-9.3-6

IF-300 PWR Cask Accident Condition Dose Rates at 1 m from the Cask

LOCATION	CURRENT LICENSED DESIGN (CSAR 1995), mrem/h			SIX GROUP III PWR ASSEMBLIES WITH 442 KG URANIUM LOADING mrem/h		
	NEUTRON	GAMMA	TOTAL	NEUTRON[1]	GAMMA[2]	TOTAL
RADIAL CL	163.06	18.10	181.16	420.69	15.02	435.72
10 CFR 71 LIMIT			1000			1000

[1] Estimated neutron dose rate was calculated by multiplying the CSAR neutron dose rate from Table A-5.4-5 times the ratio of the GIII assembly neutron source term to the analysis basis assembly neutron source term (from Section D-9.3.4.1, 2.58 = 6.88E8/2.67E8 n/s).

[2] Estimated gamma dose rate was calculated by multiplying the CSAR gamma dose rate from Table A-5.4-5 times the ratio of the assembly gamma source term for GIII assemblies to that for the analysis basis fuel (from Section D-9.3.4.2, 0.83 = 9.35E15/1.13E16 g/s).

D-9.3.5 Criticality Assessment

In order to demonstrate that the small increase in uranium loading from 437 to 442 kg/assembly has a negligible impact on the criticality assessment for the IF-300 Cask, two MCNP criticality cases from Section 6 were rerun with the increased uranium loading. The MCNP input files for both cases are included in Appendix D-9.4. MCNP was run on Duratek Federal Services Northwest Computer Serial Number 0022738297.

The first case is for a single IF-300 containing six GIII PWR fuel assemblies with a maximum lattice average enrichment of 4.25 wt% ^{235}U loaded in the peripheral PWR basket locations (i.e., with the center basket location empty) and with a 12 in close-fitting water reflector around the cask. This case is identified as case Pso6-10 in Table D-6.4-3 and resulted in the highest k_{tot} (0.94427) for the single cask cases. The MCNP input file for case Pso6-10 was modified by slightly increasing the UO_2 density in the fuel to yield a 442 kg uranium loading per assembly. The remaining input for the MCNP model was unchanged. This case (Pso6-10a) resulted in a k_{tot} of 0.94317, which is within 1 standard deviation (σ = 0.00117) of the k_{tot} for the original case (0.94427).

In Section D-6.6.1, a series of array cases were run with the maximum k_{tot} value of 0.94636 occurring for MCNP case pso6i10a (see Table D-6.6-1). This case is for an infinite array of IF-300 casks containing six GIII PWR fuel assemblies with a maximum lattice average enrichment of 4.25 wt% ^{235}U loaded in the peripheral PWR basket locations (i.e., with the center basket location empty). The MCNP input file for case pso6i10a was modified by slightly increasing the UO_2 density in the fuel to produce a 442 kg uranium loading per assembly. The remaining input for the MCNP model was unchanged. This case (pso6i10z) resulted in a k_{tot} of 0.94489, which is within 2 standard deviations (σ = 0.00104) of the k_{tot} for the original case (0.94636).

It is concluded that the increase in uranium mass loading from 437 to 442 kg/assembly has a negligible impact on the criticality assessment originally performed in Section D-6 because the differences between the k_{tot} values are statistically insignificant. Therefore, both a single IF-300 Cask and an infinite array of IF-300 Casks containing six 4.25 wt% ^{235}U GIII PWR fuel assemblies with a uranium loading up to 442 kg/assembly and with the center basket location empty will meet the criticality safety limit of $k_{eff} < 0.95$, which results in a criticality TI=0.

D-9.4 ORIGEN2 Input files for 442 kg/assembly for the GIII PWR Fuel

```
-1
-1
-1
RDA     ########################################################
RDA     ##   IF300 HIGH BURNUP/ENRICHMENT PWR FUEL              ##
RDA     ##   Input Filename: PWR345UE        ORIGEN2 VER2.1     ##
RDA     ##   Creation Date:          7/23/02                    ##
RDA     ##   Fuel Type:          3.45% W 15X15 ANF PWR          ##
RDA     ##   Burnup:50000 MWd/MTIHM, SP.POWER = 40MW/MTU        ##
RDA     ##   Cycle Burnup: 17.5, 17.5, 15K, PWRUE  xsect lib    ##
RDA     ##   CPL-WEIGHT,IRR HISTORY,FLX FACT=DOE/RW 0184,RV1    ##
RDA     ##   Low End Enrichment for Shielding Source Term       ##
RDA     ########################################################
LIP     0  0  0
LIB     0 1 2 3      604      605      606   9  0  0  1  39
PHO     101  102  103  10
RDA     READ UNIT AMOUNTS OF FUEL AND FUEL ASSEMBLY MATERIALS
RDA     -1 = FRESH PWR FUEL WITH IMPURITIES (1 MT = 1000 KG)
RDA     -2 = FRESH ZIRCALOY COMPOSITION (1 KG)
RDA     -3 = FRESH SS 304 COMPOSITION (1 KG)
RDA     -4 = FRESH INCONEL-X750 COMPOSITION (1 KG)
RDA     -5 = FRESH INCONEL-718 COMPOSITION (1 KG)
TIT   INITIAL COMP. OF UNIT AMOUNTS OF FUEL AND STRUCTURAL MAT'LS
RDA     READ FUEL COMPOSITION INCLUDING IMPURITIES (1000 KG)
INP     -1   1  -1  -1  1  1
RDA     READ ZIRCALOY COMPOSITION (1.0 KG)
INP     -2   1  -1  -1  1  1
RDA     READ SS304 COMPOSITION (1.0 KG)
INP     -3   1  -1  -1  1  1
RDA     READ INCONEL X750 COMPOSITION (1.0 KG)
INP     -4   1  -1  -1  1  1
RDA     READ INCONEL 718 COMPOSITION (1.0 KG)
INP     -5   1  -1  -1  1  1
RDA      MIX TOP, PLENUM, IN-CORE, AND BOTTOM MIXTURES
RDA      MIX TOP ZONE
MOV          -3        1        0    6.381  SS304
ADD          -4        1        0    0.024  INCONEL-X750
ADD          -5        1        0    0.672  INCONEL-718
RDA      MIX PLENUM ZONE
MOV          -4        2        0    3.019  INCONEL-X750
ADD          -2        2        0    7.551  ZIRCALOY-4
RDA      MIX IN-CORE ZONE WITHOUT UO2
MOV          -5        3        0    0.112  INCONEL-718
ADD          -2        3        0  133.927  ZIRCALOY-4
RDA      MIX BOTTOM ZONE
MOV          -3        4        0    4.459  SS304
RDA      MOVE MIXTURES INTO SCRATCH VECTORS
MOV          -1       -5        0      1.0  IN CORE U ONLY
MOV           1       -1        0      1.0  TOP ZONE
MOV           2       -2        0      1.0  PLENUM ZONE
MOV           3       -3        0      1.0  INCORE W/O UO2
MOV           4       -4        0      1.0  BOTTOM NOZZLE
RDA     IRRADIATION OF ONE METRIC TON OF PWRU FUEL AT 100% POWER
BUP
IRP    75        40.0  -5   1   4  2   BURNUP= 3,000 MWD/MTIHM
IRP    150       40.0   1   2   4  0   BURNUP= 6,000 MWD/MTIHM
IRP    225       40.0   2   3   4  0   BURNUP= 9,000 MWD/MTIHM
IRP    300       40.0   3   4   4  0   BURNUP=12,000 MWD/MTIHM
IRP    375       40.0   4   5   4  0   BURNUP=15,000 MWD/MTIHM
IRP    437.5     40.0   5   5   4  0   BURNUP=17,500 MWD/MTIHM
DEC    543.5            5   6   4  0   DECAY FOR 106.0 DAYS
IRP    618.5     40.0   6   7   4  0   BURNUP=20,500 MWD/MTIHM
IRP    693.5     40.0   7   8   4  0   BURNUP=23,500 MWD/MTIHM
IRP    768.5     40.0   8   9   4  0   BURNUP=26,500 MWD/MTIHM
```

```
IRP    843.5      40.0   9  10    4  0    BURNUP=29,500 MWD/MTIHM
IRP    918.5      40.0  10  11    4  0    BURNUP=32,500 MWD/MTIHM
IRP    981        40.0  11  11    4  0    BURNUP=35,000 MWD/MTIHM
DEC    1087             11  12    4  0    DECAY FOR 106.0 DAYS
IRP    1162       40.0  12   1    4  0    BURNUP=38,000 MWD/MTIHM
IRP    1237       40.0   1   2    4  0    BURNUP=41,000 MWD/MTIHM
IRP    1312       40.0   2   3    4  0    BURNUP=44,000 MWD/MTIHM
IRP    1387       40.0   3   4    4  0    BURNUP=47,000 MWD/MTIHM
IRP    1462       40.0   4   5    4  0    BURNUP=50,000 MWD/MTIHM
BUP
RDA    -5  = IRRADIATED UO2 FUEL AT DISCHARGE 0.442 MTU/FA
MOV      5   -5      0       0.442
RDA
RDA     IRRADIATION OF INCORE MATERIAL WITHOUT UO2 AT 100% FLUX
IRF    75.0       -1.0  -3   1    4  2    BURNUP= 3,000 MWD/MTIHM
IRF    150        -1.0   1   2    4  0    BURNUP= 6,000 MWD/MTIHM
IRF    225        -1.0   2   3    4  0    BURNUP= 9,000 MWD/MTIHM
IRF    300        -1.0   3   4    4  0    BURNUP=12,000 MWD/MTIHM
IRF    375        -1.0   4   5    4  0    BURNUP=15,000 MWD/MTIHM
IRF    437.5      -1.0   5   5    4  0    BURNUP=17,500 MWD/MTIHM
DEC    543.5             5   6    4  0    DECAY FOR 106.0 DAYS
IRF    618.5      -1.0   6   7    4  0    BURNUP=20,500 MWD/MTIHM
IRF    693.5      -1.0   7   8    4  0    BURNUP=23,500 MWD/MTIHM
IRF    768.5      -1.0   8   9    4  0    BURNUP=26,500 MWD/MTIHM
IRF    843.5      -1.0   9  10    4  0    BURNUP=29,500 MWD/MTIHM
IRF    918.5      -1.0  10  11    4  0    BURNUP=32,500 MWD/MTIHM
IRF    981        -1.0  11  11    4  0    BURNUP=35,000 MWD/MTIHM
DEC    1087             11  12    4  0    DECAY FOR 106.0 DAYS
IRF    1162       -1.0  12   1    4  0    BURNUP=38,000 MWD/MTIHM
IRF    1237       -1.0   1   2    4  0    BURNUP=41,000 MWD/MTIHM
IRF    1312       -1.0   2   3    4  0    BURNUP=44,000 MWD/MTIHM
IRF    1387       -1.0   3   4    4  0    BURNUP=47,000 MWD/MTIHM
IRF    1462       -1.0   4  -3    4  0    BURNUP=50,000 MWD/MTIHM
RDA
RDA    -3 = IRRADIATED INCORE MATERIAL WITHOUT UO2
RDA
RDA     IRRADIATION OF TOP NOZZLE MATERIAL AT 10% FLUX
RDA
IRF     75.0      -0.1  -1   1    4  2    BURNUP= 3,000 MWD/MTIHM
IRF    150        -0.1   1   2    4  0    BURNUP= 6,000 MWD/MTIHM
IRF    225        -0.1   2   3    4  0    BURNUP= 9,000 MWD/MTIHM
IRF    300        -0.1   3   4    4  0    BURNUP=12,000 MWD/MTIHM
IRF    375        -0.1   4   5    4  0    BURNUP=15,000 MWD/MTIHM
IRF    437.5      -0.1   5   5    4  0    BURNUP=17,500 MWD/MTIHM
DEC    543.5             5   6    4  0    DECAY FOR 106.0 DAYS
IRF    618.5      -0.1   6   7    4  0    BURNUP=20,500 MWD/MTIHM
IRF    693.5      -0.1   7   8    4  0    BURNUP=23,500 MWD/MTIHM
IRF    768.5      -0.1   8   9    4  0    BURNUP=26,500 MWD/MTIHM
IRF    843.5      -0.1   9  10    4  0    BURNUP=29,500 MWD/MTIHM
IRF    918.5      -0.1  10  11    4  0    BURNUP=32,500 MWD/MTIHM
IRF    981        -0.1  11  11    4  0    BURNUP=35,000 MWD/MTIHM
DEC    1087             11  12    4  0    DECAY FOR 106.0 DAYS
IRF    1162       -0.1  12   1    4  0    BURNUP=38,000 MWD/MTIHM
IRF    1237       -0.1   1   2    4  0    BURNUP=41,000 MWD/MTIHM
IRF    1312       -0.1   2   3    4  0    BURNUP=44,000 MWD/MTIHM
IRF    1387       -0.1   3   4    4  0    BURNUP=47,000 MWD/MTIHM
IRF    1462       -0.1   4  -1    4  0    BURNUP=50,000 MWD/MTIHM
RDA
RDA    -1 = IRRADIATED TOP NOZZLE MATERIAL
RDA
RDA     IRRADIATION OF PLENUM ZONE MATERIAL AT 20% FLUX
RDA
IRF     75.0      -0.2  -2   1    4  2    BURNUP= 3,000 MWD/MTIHM
IRF    150        -0.2   1   2    4  0    BURNUP= 6,000 MWD/MTIHM
IRF    225        -0.2   2   3    4  0    BURNUP= 9,000 MWD/MTIHM
IRF    300        -0.2   3   4    4  0    BURNUP=12,000 MWD/MTIHM
IRF    375        -0.2   4   5    4  0    BURNUP=15,000 MWD/MTIHM
IRF    437.5      -0.2   5   5    4  0    BURNUP=17,500 MWD/MTIHM
DEC    543.5             5   6    4  0    DECAY FOR 106.0 DAYS
```

```
IRF    618.5     -0.2   6   7   4  0   BURNUP=20,500 MWD/MTIHM
IRF    693.5     -0.2   7   8   4  0   BURNUP=23,500 MWD/MTIHM
IRF    768.5     -0.2   8   9   4  0   BURNUP=26,500 MWD/MTIHM
IRF    843.5     -0.2   9  10   4  0   BURNUP=29,500 MWD/MTIHM
IRF    918.5     -0.2  10  11   4  0   BURNUP=32,500 MWD/MTIHM
IRF    981       -0.2  11  11   4  0   BURNUP=35,000 MWD/MTIHM
DEC    1087            11  12   4  0   DECAY FOR 106.0 DAYS
IRF    1162      -0.2  12   1   4  0   BURNUP=38,000 MWD/MTIHM
IRF    1237      -0.2   1   2   4  0   BURNUP=41,000 MWD/MTIHM
IRF    1312      -0.2   2   3   4  0   BURNUP=44,000 MWD/MTIHM
IRF    1387      -0.2   3   4   4  0   BURNUP=47,000 MWD/MTIHM
IRF    1462      -0.2   4  -2   4  0   BURNUP=50,000 MWD/MTIHM
RDA
RDA    -2 = IRRADIATED PLENUM ZONE MATERIAL
RDA
RDA     IRRADIATION OF BOTTOM NOZZLE MATERIAL AT 20% FLUX
RDA
IRF     75.0     -0.2  -4   1   4  2   BURNUP= 3,000 MWD/MTIHM
IRF    150       -0.2   1   2   4  0   BURNUP= 6,000 MWD/MTIHM
IRF    225       -0.2   2   3   4  0   BURNUP= 9,000 MWD/MTIHM
IRF    300       -0.2   3   4   4  0   BURNUP=12,000 MWD/MTIHM
IRF    375       -0.2   4   5   4  0   BURNUP=15,000 MWD/MTIHM
IRF    437.5     -0.2   5   5   4  0   BURNUP=17,500 MWD/MTIHM
DEC    543.5            5   6   4  0   DECAY FOR 106.0 DAYS
IRF    618.5     -0.2   6   7   4  0   BURNUP=20,500 MWD/MTIHM
IRF    693.5     -0.2   7   8   4  0   BURNUP=23,500 MWD/MTIHM
IRF    768.5     -0.2   8   9   4  0   BURNUP=26,500 MWD/MTIHM
IRF    843.5     -0.2   9  10   4  0   BURNUP=29,500 MWD/MTIHM
IRF    918.5     -0.2  10  11   4  0   BURNUP=32,500 MWD/MTIHM
IRF    981       -0.2  11  11   4  0   BURNUP=35,000 MWD/MTIHM
DEC    1087            11  12   4  0   DECAY FOR 106.0 DAYS
IRF    1162      -0.2  12   1   4  0   BURNUP=38,000 MWD/MTIHM
IRF    1237      -0.2   1   2   4  0   BURNUP=41,000 MWD/MTIHM
IRF    1312      -0.2   2   3   4  0   BURNUP=44,000 MWD/MTIHM
IRF    1387      -0.2   3   4   4  0   BURNUP=47,000 MWD/MTIHM
IRF    1462      -0.2   4  -4   4  0   BURNUP=50,000 MWD/MTIHM
RDA    -4 = IRRADIATED BOTTOM NOZZLE MATERIAL
RDA
RDA      ADD VECTORS 1-5 TO CREATE A WHOLE FUEL ASSEMBLY
MOV           -1        -6        0       1.0
ADD           -2        -6        0       1.0
ADD           -3        -6        0       1.0
ADD           -4        -6        0       1.0
ADD           -5        -6        0       1.0
MOV           -6        -7        0       1.0
RDA
RDA       1 = IRRADIATED WHOLE ASSEMBLY AT DISCHARGE
TIT      SOURCE FOR 3.45%, 50 GWD/MTU PWR FUEL AT 0.442 MTU/FA
DEC            1        -7        1        1        2
DEC            1         1        2        5        0
DEC            2         2        3        5        0
DEC            3         3        4        5        0
DEC            4         4        5        5        0
DEC            5         5        6        5        0
BAS      ONE W 15X15 ANF PWR FUEL ASSEMBLY
OPTL     8 8 8 8 8   8 7 8 7 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
OPTA     8 8 8 8 8   8 7 8 7 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
OPTF     8 8 8 8 8   8 7 8 7 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
CUT      7  1.0e-8   9  0.01   25  0.01   25  0.01  27  0.01   -1
OUT      6   1   -1   0
STP      4
2   922340  89.0     922350 34500.0   922360    46.0    922380 965365.0  FUEL 3.45%
4   030000  1.0      050000 1.0       060000    89.4    070000 25.0      FUEL IMPU
4   080000 134454.   090000 10.7      110000    15.0    120000  2.0      FUEL IMPU
4   130000  16.7     140000 12.1      150000    35.0    170000  5.3      FUEL IMPU
4   200000  2.0      220000 1.0       230000    3.0     240000  4.0      FUEL IMPU
4   250000  1.7      260000 18.0      270000    1.0     280000 24.0      FUEL IMPU
4   290000  1.0      300000 40.3      420000    10.0    470000 0.1       FUEL IMPU
4   480000  25.0     490000 2.0       500000    4.0     640000 2.5       FUEL IMPU
```

```
4   740000  2.0      820000 1.0      830000   0.4     0      0.0         FUEL IMPU
0
4   400000  979.069  500000 16.0     260000   2.25    240000 1.25        ZIRC-4
4   280000  0.02     130000 0.024    050000 0.00033   480000 0.00025     ZIRC-4
4   060000  0.120    270000 0.010    290000   0.020   720000 0.078       ZIRC-4
4   010000  0.013    250000 0.020    070000   0.080   080000 0.950       ZIRC-4
4   160000  0.035    220000 0.020    740000   0.020   230000 0.020       ZIRC-4
5   920000  0.0002   410000 0.12      0        0.0      0    0.0         ZIRC-4
0
4   260000  687.15   240000 190.0    280000   89.2    250000 20.0        SS-304
4   060000  0.8      150000 0.45     160000   0.3     140000 10.0        SS-304
4   070000  1.3      270000 0.8      410000   0.12     0     0.0         SS-304
0
4   260000  67.846   240000 149.660  280000 721.859  130000 7.982        INC-750
4   060000  0.399    270000 6.485    290000   0.499   250000 6.984       INC-750
4   420000  0.0000   070000 1.3      410000   8.980   160000 0.07        INC-750
4   140000  2.993    220000 24.943        0   0.0      0     0.0         INC-750
0
4   260000 179.766   240000 189.753  280000 519.623  130000 5.992        INC-718
4   060000  0.4      270000 4.694    290000   0.999   250000 1.997       INC-718
4   420000  29.961   070000 1.3      410000  55.458   160000 0.07        INC-718
4   140000  1.997    220000 7.99          0   0.0      0     0.0         INC-718
0
END


-1
-1
-1
RDA      ######################################################
RDA      ##   IF300 HIGH BURNUP/ENRICHMENT PWR FUEL              ##
RDA      ##   Input Filename: P425UE          ORIGEN2 VER2.1   ##
RDA      ##   Creation Date:          7/23/02                  ##
RDA      ##   Fuel Type:          4.25% W 15X15 ANF PWR        ##
RDA      ##   Burnup:50000 MWd/MTIHM, SP.POWER = 40MW/MTU      ##
RDA      ##   Cycle Burnup: 17.5, 17.5, 15K, PWRUE  xsect lib  ##
RDA      ##   CPL-WEIGHT,IRR HISTORY,FLX FACT=DOE/RW 0184,RV1  ##
RDA      ######################################################
LIP      0  0  0
LIB      0 1 2 3      604      605     606    9   0   0   1   39
PHO      101  102  103  10
RDA     READ UNIT AMOUNTS OF FUEL AND FUEL ASSEMBLY MATERIALS
RDA     -1 = FRESH PWR FUEL WITH IMPURITIES (1 MT = 1000 KG)
TIT   INITIAL COMP. OF UNIT AMOUNTS OF FUEL AND STRUCTURAL MAT'LS
RDA     READ FUEL COMPOSITION INCLUDING IMPURITIES (1000 KG)
INP     -1   1  -1  -1  1  1
RDA     IRRADIATION OF ONE METRIC TON OF PWRU FUEL AT 100% POWER
BUP
IRP    75         40.0  -1    1    4   2   BURNUP= 3,000 MWD/MTIHM
IRP    150        40.0   1    2    4   0   BURNUP= 6,000 MWD/MTIHM
IRP    225        40.0   2    3    4   0   BURNUP= 9,000 MWD/MTIHM
IRP    300        40.0   3    4    4   0   BURNUP=12,000 MWD/MTIHM
IRP    375        40.0   4    5    4   0   BURNUP=15,000 MWD/MTIHM
IRP    437.5      40.0   5    5    4   0   BURNUP=17,500 MWD/MTIHM
DEC    543.5             5    6    4   0   DECAY FOR 106.0 DAYS
IRP    618.5      40.0   6    7    4   0   BURNUP=20,500 MWD/MTIHM
IRP    693.5      40.0   7    8    4   0   BURNUP=23,500 MWD/MTIHM
IRP    768.5      40.0   8    9    4   0   BURNUP=26,500 MWD/MTIHM
IRP    843.5      40.0   9   10    4   0   BURNUP=29,500 MWD/MTIHM
IRP    918.5      40.0  10   11    4   0   BURNUP=32,500 MWD/MTIHM
IRP    981        40.0  11   11    4   0   BURNUP=35,000 MWD/MTIHM
DEC    1087             11   12    4   0   DECAY FOR 106.0 DAYS
IRP    1162       40.0  12    1    4   0   BURNUP=38,000 MWD/MTIHM
IRP    1237       40.0   1   -2    4   0   BURNUP=41,000 MWD/MTIHM
IRP    1312       40.0  -2   -3    4   0   BURNUP=44,000 MWD/MTIHM
IRP    1387       40.0  -3   -4    4   0   BURNUP=47,000 MWD/MTIHM
IRP    1462       40.0  -4   -5    4   0   BURNUP=50,000 MWD/MTIHM
BUP
```

```
RDA     IRRADIATED UO2 FUEL - 0.442 MTU/FA
MOV       -5    -7       0       0.442
RDA
RDA        1 = IRRADIATED WHOLE ASSEMBLY AT DISCHARGE
TIT       SOURCE FOR 4.25%, 50 GWD/MTU PWR FUEL AT 0.442 MTU/FA
DEC              1        -7         1         1         2
DEC              1         1         2         5         0
DEC              2         2         3         5         0
DEC              3         3         4         5         0
DEC              4         4         5         5         0
DEC              5         5         6         5         0
BAS       ONE W 15X15 ANF PWR FUEL ASSEMBLY
HED      1  DISCHARGE
OPTL      8 8 8 8 7   8 7 8 7 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
OPTA      8 8 8 8 7   8 7 8 7 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
OPTF      8 8 8 8 7   8 7 8 7 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
CUT       7  0.0001   9  0.01   25  0.01   25  0.01  27  0.01   -1
OUT       6   1   -1   0
STP       4
2   922340   89.     922350 42500.    922360    46.    922380 957365.   FUEL 4.25%
4   030000  1.0      050000 1.0       060000   89.4    070000 25.0      FUEL IMPU
4   080000 134454.   090000 10.7      110000   15.0    120000  2.0      FUEL IMPU
4   130000  16.7     140000 12.1      150000   35.0    170000  5.3      FUEL IMPU
4   200000  2.0      220000 1.0       230000   3.0     240000  4.0      FUEL IMPU
4   250000  1.7      260000 18.0      270000   1.0     280000 24.0      FUEL IMPU
4   290000  1.0      300000 40.3      420000   10.0    470000 0.1       FUEL IMPU
4   480000  25.0     490000 2.0       500000   4.0     640000 2.5       FUEL IMPU
4   740000  2.0      820000 1.0       830000   0.4     0      0.0       FUEL IMPU
0
               END
```

D-9.5 MCNP Input files for 442 kg/assembly for the GIII PWR Fuel

Case Pso6-10a

```
PWR Cask - 6 FAs  - 4.25% - 1.00 g/cc - 12 in Refl - Shift out
1     1 -10.406 -1      22 -23        u=1 imp:n=1 $ Enriched uo2 fuel
2     4 -1.000     1 -2 22 -23        u=1 imp:n=1 $ gap - H2O
3     3 -6.565  2 -3   22 -23        u=1 imp:n=1 $ Zr4 Clad
4     4 -1.00  3 16 -17 18 -19 22 -23 u=1 imp:n=1 $ Moderator
501   4 -1.0   (-16:17:-18:19) 22  -467 u=1 imp:n=1 $ Spacer - Moderator
502   3 -6.565 (-16:17:-18:19) 467 -466 u=1 imp:n=1 $ Zr4 - 2nd Spacer
503   4 -1.0   (-16:17:-18:19) 466 -465 u=1 imp:n=1 $ Spacer - Moderator
504   3 -6.565 (-16:17:-18:19) 465 -464 u=1 imp:n=1 $ Zr4 - 3rd Spacer
505   4 -1.0   (-16:17:-18:19) 464 -463 u=1 imp:n=1 $ Spacer - Moderator
506   3 -6.565 (-16:17:-18:19) 463 -462 u=1 imp:n=1 $ Zr4 - 4th Spacer
507   4 -1.0   (-16:17:-18:19) 462 -461 u=1 imp:n=1 $ Spacer - Moderator
508   3 -6.565 (-16:17:-18:19) 461 -460 u=1 imp:n=1 $ Zr4 - 5th Spacer
509   4 -1.0   (-16:17:-18:19) 460 -459 u=1 imp:n=1 $ Spacer - Moderator
510   3 -6.565 (-16:17:-18:19) 459 -458 u=1 imp:n=1 $ Zr4 - 6th Spacer
511   4 -1.0   (-16:17:-18:19) 458 -457 u=1 imp:n=1 $ Spacer - Moderator
512   3 -6.565 (-16:17:-18:19) 457 -456 u=1 imp:n=1 $ Zr4 - 7th Spacer
513   4 -1.0   (-16:17:-18:19) 456 -455 u=1 imp:n=1 $ Spacer - Moderator
514   3 -6.565 (-16:17:-18:19) 455 -454 u=1 imp:n=1 $ Zr4 - 8th Spacer
515   4 -1.0   (-16:17:-18:19) 454 -453 u=1 imp:n=1 $ Spacer - Moderator
516   3 -6.565 (-16:17:-18:19) 453 -452 u=1 imp:n=1 $ Zr4 - 9th Spacer
517   4 -1.0   (-16:17:-18:19) 452  -23 u=1 imp:n=1 $ Spacer - Moderator
c     Natural Uranium blanket - Top
5     5 -10.406 -1      23 -21        u=1 imp:n=1 $ Natural uo2 fuel
6     4 -1.000     1 -2 23 -21        u=1 imp:n=1 $ gap - H2O
7     3 -6.565  2 -3   23 -21        u=1 imp:n=1 $ Zr4 Clad
8     4 -1.0   3              23 -21 u=1 imp:n=1 $ Moderator
c     Natural Uranium blanket - Bottom
9     5 -10.406 -1      20 -22        u=1 imp:n=1 $ Natural uo2 fuel
10    4 -1.000     1 -2 20 -22        u=1 imp:n=1 $ gap - H2O
11    3 -6.565  2 -3   20 -22        u=1 imp:n=1 $ Zr4 Clad
12    4 -1.0   3              20 -22 u=1 imp:n=1 $ Moderator
c     Plenum region - below fuel pins
13    4 -1.000     -2   24 -20        u=1 imp:n=1 $ He
14    3 -6.565  2 -3   24 -20        u=1 imp:n=1 $ Zr4 Clad
15    4 -1.00  3        24 -20        u=1 imp:n=1 $ Moderator
c     Plenum region - above fuel pins
16    4 -1.000     -2   21 -25        u=1 imp:n=1 $ He
17    3 -6.565  2 -3   21 -25        u=1 imp:n=1 $ Zr4 Clad
18    4 -1.00  3        21 -25        u=1 imp:n=1 $ Moderator
c     Rest of Lower tie plate - below fuel pins
19    6 -8.03  30 -24                 u=1 imp:n=1 $ 304L SS in LTP
c     Water below Lower tie plate/above channel bottom -below fuel pins
191   4 -1.00  -30                    u=1 imp:n=1 $ Water
c     Rest of Upper tie plate - above fuel pins
20    6 -8.03  25                     u=1 imp:n=1 $ 304L SS in LTP
c     Lattice of Cells - Top of water above UTP to water below LTP
25    0 4 -5 6 -7  lat=1 u=2  fill= -7:7  -7:7 0:0
         1 1 1 1 1 1 1 1 1 1 1 1 1 1 1          $ x=-7 to x=7:y=7
         1 1 1 1 1 1 1 1 1 1 1 1 1 1 1          $ "          ";y=6
         1 1 3 1 1 3 1 1 1 3 1 1 3 1 1          $ "          ";y=5
         1 1 1 1 1 1 1 3 1 1 1 1 1 1 1          $ "          ";y=4
         1 1 1 1 3 1 1 1 1 1 3 1 1 1 1          $ "          ";y=3
         1 1 3 1 1 1 1 1 1 1 1 1 3 1 1          $ "          ";y=2
         1 1 1 1 1 1 1 1 1 1 1 1 1 1 1          $ "          ";y=1
         1 1 1 3 1 1 1 3 1 1 1 3 1 1 1          $ "          ";y=0
         1 1 1 1 1 1 1 1 1 1 1 1 1 1 1          $ "          ":y=-1
         1 1 3 1 1 1 1 1 1 1 1 1 3 1 1          $ "          ";y=-2
         1 1 1 1 3 1 1 1 1 1 3 1 1 1 1          $ "          ";y=-3
         1 1 1 1 1 1 1 3 1 1 1 1 1 1 1          $ "          ";y=-4
         1 1 3 1 1 3 1 1 1 3 1 1 3 1 1          $ "          ";y=-5
         1 1 1 1 1 1 1 1 1 1 1 1 1 1 1          $ "          ";y=-6
         1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 imp:n=1 $ "          ";y=-7
```

```
c      Instrument/Control Rod Guide Tubes
26     4 -1.00 -10      24 -25        u=3 imp:n=1 $ water inside tube
27     3 -6.565 10 -11 24 -25        u=3 imp:n=1 $ Zr4 Clad
28     4 -1.0    11 16 -17 18 -19   24  -25 u=3 imp:n=1 $ Moderator
281    4 -1.0    (-16:17:-18:19)  24 -467 u=3 imp:n=1 $ Spacer - Moderator
282    3 -6.565 (-16:17:-18:19) 467 -466 u=3 imp:n=1 $ Zr4 - 2nd Spacer
283    4 -1.0    (-16:17:-18:19) 466 -465 u=3 imp:n=1 $ Spacer - Moderator
284    3 -6.565 (-16:17:-18:19) 465 -464 u=3 imp:n=1 $ Zr4 - 3rd Spacer
285    4 -1.0    (-16:17:-18:19) 464 -463 u=3 imp:n=1 $ Spacer - Moderator
286    3 -6.565 (-16:17:-18:19) 463 -462 u=3 imp:n=1 $ Zr4 - 4th Spacer
287    4 -1.0    (-16:17:-18:19) 462 -461 u=3 imp:n=1 $ Spacer - Moderator
288    3 -6.565 (-16:17:-18:19) 461 -460 u=3 imp:n=1 $ Zr4 - 5th Spacer
289    4 -1.0    (-16:17:-18:19) 460 -459 u=3 imp:n=1 $ Spacer - Moderator
290    3 -6.565 (-16:17:-18:19) 459 -458 u=3 imp:n=1 $ Zr4 - 6th Spacer
291    4 -1.0    (-16:17:-18:19) 458 -457 u=3 imp:n=1 $ Spacer - Moderator
292    3 -6.565 (-16:17:-18:19) 457 -456 u=3 imp:n=1 $ Zr4 - 7th Spacer
293    4 -1.0    (-16:17:-18:19) 456 -455 u=3 imp:n=1 $ Spacer - Moderator
294    3 -6.565 (-16:17:-18:19) 455 -454 u=3 imp:n=1 $ Zr4 - 8th Spacer
295    4 -1.0    (-16:17:-18:19) 454 -453 u=3 imp:n=1 $ Spacer - Moderator
296    3 -6.565 (-16:17:-18:19) 453 -452 u=3 imp:n=1 $ Zr4 - 9th Spacer
297    4 -1.0    (-16:17:-18:19) 452 -25  u=3 imp:n=1 $ Spacer - Moderator
c      Lower Tie Plate
c      Instrument/Control Rod Guide Tube Locations
29     4 -1.00 -10         -24 30     u=3 imp:n=1 $ water inside tube
30     3 -6.565 10 -11     -24 30     u=3 imp:n=1 $ Zr4 Clad
31     6 -8.03 11          -24 30     u=3 imp:n=1 $ 304L SS in LTP
c      Water below Lower tie plate/above channel bottom -below fuel pins
311    4 -1.00  -30                    u=3 imp:n=1 $ Water
c      Upper Tie Plate
c      Instrument/Control Rod Guide Tube Locations
33     4 -1.00 -10      25            u=3 imp:n=1 $ water inside tube
34     3 -6.565 10 -11 25             u=3 imp:n=1 $ Zr4 Clad
35     6 -8.03 11      25             u=3 imp:n=1 $ 304L SS in UTP
c      Fuel Assembly
c
36      0 12 -13 14 -15 26 -31 u=42 fill=2 trcl=132 imp:n=1 $ FA #2
363     0 12 -13 14 -15 26 -31 u=43 fill=2 trcl=133 imp:n=1 $ FA #3
364     0 12 -13 14 -15 26 -31 u=44 fill=2 trcl=134 imp:n=1 $ FA #4
365     0 12 -13 14 -15 26 -31 u=45 fill=2 trcl=135 imp:n=1 $ FA #5
366     0 12 -13 14 -15 26 -31 u=46 fill=2 trcl=136 imp:n=1 $ FA #6
367     0 12 -13 14 -15 26 -31 u=47 fill=2 trcl=137 imp:n=1 $ FA #7
c
c      Water Gap between fuel assembly and guide channel
c      and above UTP.
c
40     4 -1.0     (41 -42 45 -46 26)       u=4  imp:n=1   $ FA #1 - Center Hole
402    4 -1.0     (41 -42 45 -46 26) #36  u=42 imp:n=1   $ FA #2
403    4 -1.0     (41 -42 45 -46 26) #363 u=43 imp:n=1   $ FA #3
404    4 -1.0     (41 -42 45 -46 26) #364 u=44 imp:n=1   $ FA #4
405    4 -1.0     (41 -42 45 -46 26) #365 u=45 imp:n=1   $ FA #5
406    4 -1.0     (41 -42 45 -46 26) #366 u=46 imp:n=1   $ FA #6
407    4 -1.0     (41 -42 45 -46 26) #367 u=47 imp:n=1   $ FA #7
c
c      Guide Channel side & 1 in bottom plate (mixture of H2O & SS304)
41     13 -5.51326      #40  u=4  imp:n=1
412    13 -5.51326 #36  #402 u=42 imp:n=1
413    13 -5.51326 #363 #403 u=43 imp:n=1
414    13 -5.51326 #364 #404 u=44 imp:n=1
415    13 -5.51326 #365 #405 u=45 imp:n=1
416    13 -5.51326 #366 #406 u=46 imp:n=1
417    13 -5.51326 #367 #407 u=47 imp:n=1
c
c      Define a row of 6 Horizontal poison pins
c      First a pin with axial segments (poison, steel, poison, etc)
44    4 -1.0     -61      -301      u=5 imp:n=1 $ water below bottom B4C
45    10 -1.2225  -60 301 -302     u=5 imp:n=1 $ B4C reduced 75% - Pin 1
46    6 -8.03  60 -61 301 -302     u=5 imp:n=1 $ poison pin SS clad
461   6 -8.03      -61 302 -303    u=5 imp:n=1 $ Steel
462   10 -1.2225  -60 303 -304     u=5 imp:n=1 $ B4C reduced 75% - Pin 2
```

```
463  6 -8.03   60 -61 303 -304     u=5 imp:n=1 $ poison pin SS clad
464  6 -8.03      -61 304 -305     u=5 imp:n=1 $ Steel
465  10 -1.2225   -60 305 -306     u=5 imp:n=1 $ B4C reduced 75% - Pin 3
466  6 -8.03   60 -61 305 -306     u=5 imp:n=1 $ poison pin SS clad
467  6 -8.03      -61 306 -307     u=5 imp:n=1 $ Steel
468  10 -1.2225   -60 307 -308     u=5 imp:n=1 $ B4C reduced 75% - Pin 4
469  6 -8.03   60 -61 307 -308     u=5 imp:n=1 $ poison pin SS clad
470  6 -8.03      -61 308 -309     u=5 imp:n=1 $ Steel
471  10 -1.2225   -60 309 -310     u=5 imp:n=1 $ B4C reduced 75% - Pin 5
472  6 -8.03   60 -61 309 -310     u=5 imp:n=1 $ poison pin SS clad
473  6 -8.03      -61 310 -311     u=5 imp:n=1 $ Steel
474  10 -1.2225   -60 311 -312     u=5 imp:n=1 $ B4C reduced 75% - Pin 6
475  6 -8.03   60 -61 311 -312     u=5 imp:n=1 $ poison pin SS clad
476  6 -8.03      -61 312 -313     u=5 imp:n=1 $ Steel
477  10 -1.2225   -60 313 -314     u=5 imp:n=1 $ B4C reduced 75% - Pin 7
478  6 -8.03   60 -61 313 -314     u=5 imp:n=1 $ poison pin SS clad
479  6 -8.03      -61 314 -315     u=5 imp:n=1 $ Steel
480  10 -1.2225   -60 315 -316     u=5 imp:n=1 $ B4C reduced 75% - Pin 8
481  6 -8.03   60 -61 315 -316     u=5 imp:n=1 $ poison pin SS clad
482  6 -8.03      -61 316 -317     u=5 imp:n=1 $ Steel
483  10 -1.2225   -60 317          u=5 imp:n=1 $ B4C reduced 75% - Pin 9
484  6 -8.03   60 -61 317          u=5 imp:n=1 $ poison pin SS clad
c
49   4 -1.0     61             u=5 imp:n=1 $ water around pins
c     Fill the lattice
60   0 76 -77 72 -73  lat=1 fill= -2:3 0:0 0:0
                      5 5 5 5 5 5  u=55    imp:n=1
c     Define the horizontal row
61   0 48 -49 72 -73 30 -31  fill=55 trcl=20 imp:n=1   $ Horiz Above FA#1
c     Define the rest of the horizontal rows
62   like 61 but trcl=21 imp:n=1 $ Horiz below FA#2
63   like 61 but trcl=22 imp:n=1 $ Horiz below FA#3
64   like 61 but trcl=23 imp:n=1 $ Horiz above FA#4
65   like 61 but trcl=24 imp:n=1 $ Horiz above FA#5
66   like 61 but trcl=25 imp:n=1 $ Horiz below FA#4
67   like 61 but trcl=26 imp:n=1 $ Horiz below FA#1
68   like 61 but trcl=27 imp:n=1 $ Horiz below FA#5
69   like 61 but trcl=28 imp:n=1 $ Horiz above FA#6
70   like 61 but trcl=29 imp:n=1 $ Horiz above FA#7
c
c     Define a column of 6 Vertical poison pins
c     First a pin with axial segments (poison, steel, poison, etc)
74   4 -1.0    -63      -301     u=6 imp:n=1 $ water below bottom B4C
75   10 -1.2225  -62 301 -302     u=6 imp:n=1 $ B4C reduced 75% - Pin 1
76   6 -8.03  62 -63 301 -302     u=6 imp:n=1 $ poison pin SS clad
761  6 -8.03     -63 302 -303     u=6 imp:n=1 $ Steel
762  10 -1.2225  -62 303 -304     u=6 imp:n=1 $ B4C reduced 75% - Pin 2
763  6 -8.03  62 -63 303 -304     u=6 imp:n=1 $ poison pin SS clad
764  6 -8.03     -63 304 -305     u=6 imp:n=1 $ Steel
765  10 -1.2225  -62 305 -306     u=6 imp:n=1 $ B4C reduced 75% - Pin 3
766  6 -8.03  62 -63 305 -306     u=6 imp:n=1 $ poison pin SS clad
767  6 -8.03     -63 306 -307     u=6 imp:n=1 $ Steel
768  10 -1.2225  -62 307 -308     u=6 imp:n=1 $ B4C reduced 75% - Pin 4
769  6 -8.03  62 -63 307 -308     u=6 imp:n=1 $ poison pin SS clad
770  6 -8.03     -63 308 -309     u=6 imp:n=1 $ Steel
771  10 -1.2225  -62 309 -310     u=6 imp:n=1 $ B4C reduced 75% - Pin 5
772  6 -8.03  62 -63 309 -310     u=6 imp:n=1 $ poison pin SS clad
773  6 -8.03     -63 310 -311     u=6 imp:n=1 $ Steel
774  10 -1.2225  -62 311 -312     u=6 imp:n=1 $ B4C reduced 75% - Pin 6
775  6 -8.03  62 -63 311 -312     u=6 imp:n=1 $ poison pin SS clad
776  6 -8.03     -63 312 -313     u=6 imp:n=1 $ Steel
777  10 -1.2225  -62 313 -314     u=6 imp:n=1 $ B4C reduced 75% - Pin 7
778  6 -8.03  62 -63 313 -314     u=6 imp:n=1 $ poison pin SS clad
779  6 -8.03     -63 314 -315     u=6 imp:n=1 $ Steel
780  10 -1.2225  -62 315 -316     u=6 imp:n=1 $ B4C reduced 75% - Pin 8
781  6 -8.03  62 -63 315 -316     u=6 imp:n=1 $ poison pin SS clad
782  6 -8.03     -63 316 -317     u=6 imp:n=1 $ Steel
783  10 -1.2225  -62 317          u=6 imp:n=1 $ B4C reduced 75% - Pin 9
784  6 -8.03  62 -63 317          u=6 imp:n=1 $ poison pin SS clad
```

```
c
79   4 -1.0     63              u=6 imp:n=1 $ water around pins
c     Fill the lattice
80   0 76 -78 79 -791  lat=1 fill=6  u=66    imp:n=1
c     Define the vertical column
81   0 44 -47 74 -75 30 -31  fill=66 trcl=30 imp:n=1   $ Vert Right of FA#2
c     Define the rest of the vertical columns
85   like 81 but trcl=31 imp:n=1 $ vert left of FA#3
86   like 81 but trcl=32 imp:n=1 $ vert rght of FA#4
87   like 81 but trcl=33 imp:n=1 $ vert left of FA#1
88   like 81 but trcl=34 imp:n=1 $ vert rght of FA#1
89   like 81 but trcl=35 imp:n=1 $ vert left of FA#5
90   like 81 but trcl=36 imp:n=1 $ vert rght of FA#6
91   like 81 but trcl=37 imp:n=1 $ vert left of FA#7
c
c     Make a dummy water FA in the center
c
42     0  40 -43 44 -47 27 -33 fill=4 imp:n=1
c
c     Define the 6 Outer FAs
c     Make a unit out of the FA, water gap, and guide channel
c
100    0  40 -43 44 -47 27 -33 fill=42 trcl=121  imp:n=1 $ FA #2
101    0  40 -43 44 -47 27 -33 fill=43 trcl=122  imp:n=1 $ FA #3
102    0  40 -43 44 -47 27 -33 fill=44 trcl=123  imp:n=1 $ FA #4
103    0  40 -43 44 -47 27 -33 fill=45 trcl=124  imp:n=1 $ FA #5
104    0  40 -43 44 -47 27 -33 fill=46 trcl=125  imp:n=1 $ FA #6
105    0  40 -43 44 -47 27 -33 fill=47 trcl=126  imp:n=1 $ FA #7
c     Define the 4 basket support rods
106   6 -8.03 -80 27 -33       imp:n=1  $ Upper left
107   6 -8.03 -81 27 -33       imp:n=1  $ Upper right
108   6 -8.03 -82 27 -33       imp:n=1  $ Lower left
109   6 -8.03 -83 27 -33       imp:n=1  $ Lower right
c
c    Define Cask Cells
c
200   6 -8.03  27 -203 100 -101 imp:n=1 $ 317 SS Inner Shell - Radial
201   6 -8.03  202 -27     -101 imp:n=1 $ 304 SS Inner Shell - Bottom
202   6 -8.03  203 -204    -101 imp:n=1 $ 304 SS Inner Shell - Top
203   11 -18.82 (-102 201 -202):(101 -102 202 -204):(-102 204 -205)
                  imp:n=1 $ Lead (union of bottom/side/top)
204   6 -8.03 (-103 200 -201):(102 -103 201 -205):(-103 205 -206)
            imp:n=1 $ 304 SST outer shell (union of bottom/side/top)
c
c     Water outside FAs in basket and inside Cask.
c
1000  4 -1.0        -100 27 -203 51 #100 #101 #62 #63 #81 #85 #106 #107
                        imp:n=1 $ FAs 2&3 Surrounded by water
1001  4 -1.00  -100 27 -203 50 -51 #42 #102 #103
            #61 #64 #65 #66 #67 #68 #86 #87 #88 #89
                        imp:n=1 $ FAs 1,4,5 Surrounded by water
1002  4 -1.00  -100 27 -203 -50 #104 #105 #69 #70 #90 #91 #108 #109
                        imp:n=1 $ FAs Surrounded by water
c
c     1st 5 cm water reflector
c
1999  4 -1.00 (206:-200:103) (-207 -104 199) imp:n=1
c
c     Remaining water reflector to 12 in
c
2000  4 -1.0 (207:-199:104) (-208 -105 198) imp:n=0.25
c
c     Outside Cask.
c
3000  0 -1000 (208:-198:105) imp:n=0

c
c     Fuel Cell
c
```

```
1      cz   .45339    $ Fuel Pellet OD
2      cz   .46228    $ Zr4 Clad ID
3      cz   .53848    $ Zr4 Clad OD
4      px -0.71501   $ fuel rod cell boundary
5      px  0.71501   $ fuel rod cell boundary
6      py -0.71501   $ fuel rod cell boundary
7      py  0.71501   $ fuel rod cell boundary
c
c      Instrument Tube/Control Rod Guide Tube
c
10     cz  0.64897   $ ID
11     cz  0.69088   $ OD
c
c      Fuel Assembly
c
12     px -10.7137   $ 1/2 FA pitch
13     px  10.7137   $ 1/2 FA pitch
14     py -10.7137   $ 1/2 FA pitch
15     py  10.7137   $ 1/2 FA pitch
c
c      Zr grid inner pitch
c
16     px -0.712475 $ Zr grid cell boundary
17     px  0.712475 $ Zr grid cell boundary
18     py -0.712475 $ Zr grid cell boundary
19     py  0.712475 $ Zr grid cell boundary
c
c      Overall Fuel Height including blanket - 144 inches
c
20     pz -182.88
21     pz  182.88
c
c      Axial Blanket/enriched fuel zone - 6 inches below top & bottom
c
22     pz -167.64
23     pz  167.64
c
c      Top and bottom plenum regions
c
24     pz -185.75
25     pz  204.673
c
c      Channel bottom plate
c
26     pz -192.151
27     pz -194.691
c
c    Lower Tie Plate - use FA px/py (8.424 in pitch vs 8.436 in for FA)
c
c      Smear mass over rectangle for now
c      Bottom of LTP
30     pz -186.953      $ Water to bottom of lowest poison pin B4C
c  Surfaces for poison pin/steel segments
301    pz -178.65725    $ Poison in lowest poison pin to steel
302    pz -138.85545    $ Steel to bottom of next poison pin B4C
303    pz -125.8062     $ Poison in next poison pin to steel
304    pz  -91.8718     $ Steel to bottom of next poison pin B4C
305    pz -78.82255     $ Poison in next poison pin to steel
306    pz -44.88815     $ Steel to bottom of next poison pin B4C
307    pz -31.8389      $ Poison in next poison pin to steel
308    pz   2.0955      $ Steel to bottom of next poison pin B4C
309    pz  15.14475     $ Poison in next poison pin to steel
310    pz  49.07915     $ Steel to bottom of next poison pin B4C
311    pz  62.1284      $ Poison in next poison pin to steel
312    pz  96.0628      $ Steel to bottom of next poison pin B4C
313    pz 109.11205     $ Poison in next poison pin to steel
314    pz 143.04645     $ Steel to bottom of next poison pin B4C
315    pz 156.0957      $ Poison in next poison pin to steel
316    pz 190.0301      $ Steel to bottom of top poison pin B4C
```

```
317   pz 203.07935    $ Poison in top poison pin to steel - through UTP
c
c    Upper Tie Plate - use FA px/py (8.424 in pitch vs 8.436 in for FA)
c
c     Smear mass over rectangle for now
c     Top of UTP
31    pz 206.538
c
33    pz 213.512  $ Top of FA
c
c     Square Cell for Channel
c
40    px  -11.3816
41    px  -11.1919
42    px   11.1919
43    px   11.3816
44    py  -11.3816
45    py  -11.1919
46    py   11.1919
47    py   11.3816
c
c     Rectangular Cell for Basket (ignore 9 - 1" thick axial spacers)
c
48    px  -11.43
49    px   11.43
50    py  -13.0548
51    py   13.0548
c
c     B4C poison pins -
60    c/z 1.905    0.8763 0.5842    $ ID of SS304 clad
61    c/z 1.905    0.8763 0.635     $ OD of SS304 clad
62    c/z 1.1049  1.905  0.5842     $ ID of SS304 clad
63    c/z 1.1049  1.905  0.635      $ OD of SS304 clad
72    py 0.0397  $
73    py 1.7129  $ 1/2 pitch for horiz poison pin row (1/2 of 1.38 in)
74    px 0.0397  $
75    px 2.3352  $ 1/2 pitch for vertic poison pin row (1/2 of 1.87 in)
76    px 0.0      $ 1/2 x dimension pitch for poison pin row
77    px 3.81
78    px 2.2098
79    py 0.0
791   py 3.81
c
c     Four Basket Support Rods - 2-1/4 inch 216 SS
c
80    c/z -29.21  26.43124  2.8575
81    c/z  29.21  26.43124  2.8575
82    c/z -29.21 -26.43124  2.8575
83    c/z  29.21 -26.43124  2.8575
c
c     Cask dimensions
c
c     Radial
100   cz    47.625    $ Inner Cavity -18.75"
101   cz    48.895    $ 317 SS inner - 0.5"
102   cz    59.055    $ Cast DU      - 4"
103   cz   63.0174    $ 317 SS outer -1.56"
104   cz   68.0174    $ 5 cm side reflector
105   cz   93.4974    $ 12 inch side reflector
c     Axial - Bottom to Top of Cask
198   pz -241.6810    $ 12 inch bottom reflector
199   pz -216.2010    $ 5 cm bottom reflector
200   pz -211.201     $ 304 SST  - 1.5"
201   pz -207.391     $ Cast DU  - 3.75"
202   pz -197.866     $ 304 SST  - 1.25"
203   pz  235.839     $ Cavity  -169.5"
204   pz  238.379     $ 304 SST - 1"
205   pz  245.999     $ Cast DU - 3"
206   pz  251.079     $ 304 SST - 2"
```

```
207  pz  256.0790   $ 5 cm top reflector
208  pz  281.5590   $ 12 inch top reflector
c
c  Axial planes for spacer grid
c
450    pz   199.3265 $ Top of top spacer
451    pz   194.8815
452    pz   152.0063
453    pz   147.5613
454    pz   117.4115
455    pz   115.5065
456    pz   85.4837
457    pz   81.0387
458    pz   50.8889
459    pz   48.9839
460    pz   18.9611
461    pz   14.5161
462    pz   -15.6337
463    pz   -17.5387
464    pz   -47.5615
465    pz   -52.0065
466    pz   -114.0841
467    pz   -118.5291
468    pz   -174.9552
469    pz   -180.6702  $ 1st spacer from bottom
1000 so 1000

c     Translations for horizontal row of 6 poison pins
tr1   -9.525  0.8763   0    $ Left
tr2   -5.715  0.8763   0    $
tr3   -1.905  0.8763   0    $
tr4    1.905  0.8763   0    $
tr5    5.715  0.8763   0    $
tr6    9.525  0.8763   0    $ Right
c     Translations for vertical row of 6 poison pins
tr11   1.18745 -9.525  0     $ Bottom
tr12   1.18745 -5.715  0     $
tr13   1.18745 -1.905  0     $
tr14   1.18745  1.905  0     $
tr15   1.18745  5.715  0     $
tr16   1.18745  9.525  0     $ Top
c     Translate horizontal poison pin rows
tr20     0.0000  11.3419     0 $ Horiz above FA#1
tr21   -13.6771  13.0151     0 $ Horiz below FA#2
tr22    13.6771  13.0151     0 $ Horiz below FA#3
tr23   -27.3542  11.3419     0 $ Horiz above FA#4
tr24    27.3542  11.3419     0 $ Horiz above FA#5
tr25   -27.3542 -13.0945     0 $ Horiz below FA#4
tr26     0.0000 -13.0945     0 $ Horiz below FA#1
tr27    27.3542 -13.0945     0 $ Horiz below FA#5
tr28   -13.6771 -14.7677     0 $ Horiz above FA#6
tr29    13.6771 -14.7677     0 $ Horiz above FA#7
c     Translate vertical poison pin rows
tr30    -2.3352  26.1096    0 $ vert rght of FA#2
tr31    -0.0397  26.1096    0 $ vert left of FA#3
tr32   -16.0123   0.0000    0 $ vert rght of FA#4
tr33   -13.7168   0.0000    0 $ vert left of FA#1
tr34    11.3419   0.0000    0 $ vert rght of FA#1
tr35    13.6374   0.0000    0 $ vert left of FA#5
tr36    -2.3352 -26.1096    0 $ vert rght of FA#6
tr37    -0.0397 -26.1096    0 $ vert left of FA#7
c     FA translations
tr121   -13.6771 26.1096   0    $ FA #2
tr122    13.6771 26.1096   0    $ FA #3
tr123   -27.3542 0         0    $ FA #4
tr124    27.3542 0         0    $ FA #5
tr125   -13.6771 -26.1096  0    $ FA #6
tr126    13.6771 -26.1096  0    $ FA #7
c     Shift FA within basket channel
```

```
tr132 -0.478  0.478 0    $ FA #2
tr133  0.478  0.478 0    $ FA #3
tr134 -0.478  0     0    $ FA #4
tr135  0.478  0     0    $ FA #5
tr136 -0.478 -0.478 0    $ FA #6
tr137  0.478 -0.478 0    $ FA #7
mode n
kcode  3000 1 30 220 50000
print -128
prdmp j -120 j 3
fc4   fission * lethargy**2 in cell 1
f4:n   1
fm4    -1  1  -6
sd4    1.0
c     lethargy**2 [base 20 MeV -- u=0 at 20 MeV]
de4   1.e-8 1.e-7 1.e-6 1.e-5 1.e-4 .001   .01    .1     1    10    14
df4   458.7 365.3 282.6 210.5 149.0 98.08 57.77 28.07 8.974 0.48 .127
fc14  fission in cell 1
f14:n  1
fm14   -1 1 -6
sd14   1.0
fc24   fission * lethargy in cell 1
f24:n   1
fm24    -1  1  -6
sd24    1.0
c     lethargy [base 20 MeV -- u=0 at 20 MeV]
de24  1.e-8 1.e-7 1.e-6 1.e-5 1.e-4 .001 .01    .1      1   10     14
df24  21.42 19.11 16.81 14.51 12.21 9.90 7.60 5.298 2.996 0.693 0.357
c     m1 is UO2 fuel - Enriched to 4.25 wt% U235
m1    92235.50c  -0.037462
      92238.50c  -0.843989
      8016.50c   -0.118549
c     m2 is He
m2    2004.50c -1.0
c     m3 is Zircaloy 4
m3    40000.60c  -98.18
      8016.50c    -0.12
      24000.50c   -0.10
      26000.55c   -0.20
      50000.35c   -1.40
c     m4 is water
m4    1001.50c 0.666700 8016.50c 0.333300
c     m5 is Natural UO2 blanket fuel - 0.72 wt% U235
m5    92235.50c -0.0062672
      92238.50c -0.875206
      8016.50c  -0.118528
c     m6 is 304L SS
m6    6000.50c     -0.03
      14000.50c       -1
      15031.50c   -0.045
      16032.50c    -0.03
      24000.50c      -20
      25055.50c       -2
      26000.55c  -64.895
      28000.50c      -12
c     m7 is Inconel 718
m7    5000.01c     -0.006
      6000.50c       -0.08
      13027.50c       -0.8
      14000.50c      -0.35
      22000.50c      -1.15
      24000.50c        -21
      25055.50c      -0.35
      26000.55c    -11.164
      27059.50c         -1
      28000.50c        -55
      29000.50c       -0.3
      41093.50c       -5.5
      42000.50c       -3.3
```

```
c     m8 is Inconel X750
m8    6000.50c   -0.08
      13027.50c     -1
      14000.50c   -0.5
      22000.50c  -2.75
      24000.50c    -15
      25055.50c     -1
      26000.55c     -7
      27059.50c     -1
      28000.50c    -70
      29000.50c   -0.5
      41093.50c   -1.2
c     m10 is B4C poison
m10   5010.50c  -0.140886  $ B10 lower end 18.3% - 0.3%
      5011.50c  -0.641812  $ B11 upper end 81.7% + 0.3%
      6000.50c  -0.217302  $ C
c     m11 is Depleted Uranium
m11   92235.50c 0.000106128
      92238.50c 0.0475275
c     m12 is Air
m12   7014.50c -0.765
      8016.50c -0.235
c     m13 is Channel - 304 SS and water mixture (VF water = 0.358)
m13   6000.50c  -0.000748
      14000.50c -0.009351
      15031.50c -0.000421
      16032.50c -0.000281
      24000.50c -0.187013
      25055.50c -0.018701
      26000.55c -0.620369
      28000.50c -0.098182
      1001.50c  -0.007266
      8016.50c  -0.057669
mt4   lwtr.01t
mt13  lwtr.01t
```

Case pso6i10z

```
PWR 6 FAs 4.25%, CTMT/INT- 1.0/0.0 -Inf Hex- 2 cm - Shifted Out - Inf T/B Refl
1     1 -10.406 -1        22 -23        u=1 imp:n=1 $ Enriched uo2 fuel
2     4 -1.0          1 -2 22 -23        u=1 imp:n=1 $ gap - H2O
3     3 -6.565  2 -3   22 -23        u=1 imp:n=1 $ Zr4 Clad
4     4 -1.0     3 16 -17 18 -19 22 -23 u=1 imp:n=1 $ Moderator
501   4 -1.0    (-16:17:-18:19) 22  -467 u=1 imp:n=1 $ Spacer - Moderator
502   3 -6.565 (-16:17:-18:19) 467 -466 u=1 imp:n=1 $ Zr4 - 2nd Spacer
503   4 -1.0    (-16:17:-18:19) 466 -465 u=1 imp:n=1 $ Spacer - Moderator
504   3 -6.565 (-16:17:-18:19) 465 -464 u=1 imp:n=1 $ Zr4 - 3rd Spacer
505   4 -1.0    (-16:17:-18:19) 464 -463 u=1 imp:n=1 $ Spacer - Moderator
506   3 -6.565 (-16:17:-18:19) 463 -462 u=1 imp:n=1 $ Zr4 - 4th Spacer
507   4 -1.0    (-16:17:-18:19) 462 -461 u=1 imp:n=1 $ Spacer - Moderator
508   3 -6.565 (-16:17:-18:19) 461 -460 u=1 imp:n=1 $ Zr4 - 5th Spacer
509   4 -1.0    (-16:17:-18:19) 460 -459 u=1 imp:n=1 $ Spacer - Moderator
510   3 -6.565 (-16:17:-18:19) 459 -458 u=1 imp:n=1 $ Zr4 - 6th Spacer
511   4 -1.0    (-16:17:-18:19) 458 -457 u=1 imp:n=1 $ Spacer - Moderator
512   3 -6.565 (-16:17:-18:19) 457 -456 u=1 imp:n=1 $ Zr4 - 7th Spacer
513   4 -1.0    (-16:17:-18:19) 456 -455 u=1 imp:n=1 $ Spacer - Moderator
514   3 -6.565 (-16:17:-18:19) 455 -454 u=1 imp:n=1 $ Zr4 - 8th Spacer
515   4 -1.0    (-16:17:-18:19) 454 -453 u=1 imp:n=1 $ Spacer - Moderator
516   3 -6.565 (-16:17:-18:19) 453 -452 u=1 imp:n=1 $ Zr4 - 9th Spacer
517   4 -1.0    (-16:17:-18:19) 452  -23 u=1 imp:n=1 $ Spacer - Moderator
c     Natural Uranium blanket - Top
5     5 -10.406 -1        23 -21        u=1 imp:n=1 $ Natural uo2 fuel
6     4 -1.0          1 -2 23 -21        u=1 imp:n=1 $ gap - H2O
7     3 -6.565  2 -3   23 -21        u=1 imp:n=1 $ Zr4 Clad
8     4 -1.0   3                23 -21 u=1 imp:n=1 $ Moderator
c     Natural Uranium blanket - Bottom
9     5 -10.406 -1        20 -22        u=1 imp:n=1 $ Natural uo2 fuel
10    4 -1.0          1 -2 20 -22        u=1 imp:n=1 $ gap - H2O
11    3 -6.565  2 -3   20 -22        u=1 imp:n=1 $ Zr4 Clad
12    4 -1.0   3                20 -22 u=1 imp:n=1 $ Moderator
c     Plenum region - below fuel pins
13    4 -1.0          -2   24 -20        u=1 imp:n=1 $ He
14    3 -6.565  2 -3   24 -20        u=1 imp:n=1 $ Zr4 Clad
15    4 -1.0      3         24 -20        u=1 imp:n=1 $ Moderator
c     Plenum region - above fuel pins
16    4 -1.0          -2   21 -25        u=1 imp:n=1 $ He
17    3 -6.565  2 -3   21 -25        u=1 imp:n=1 $ Zr4 Clad
18    4 -1.0      3         21 -25        u=1 imp:n=1 $ Moderator
c     Rest of Lower tie plate - below fuel pins
19    6 -8.03  30 -24                 u=1 imp:n=1 $ 304L SS in LTP
c     Water below Lower tie plate/above channel bottom -below fuel pins
191   4 -1.0      -30                 u=1 imp:n=1 $ Water
c     Rest of Upper tie plate - above fuel pins
20    6 -8.03  25                     u=1 imp:n=1 $ 304L SS in LTP
c     Lattice of Cells - Top of water above UTP to water below LTP
25    0 4 -5 6 -7  lat=1 u=2  fill= -7:7  -7:7 0:0
         1 1 1 1 1 1 1 1 1 1 1 1 1 1 1          $ x=-7 to x=7:y=7
         1 1 1 1 1 1 1 1 1 1 1 1 1 1 1          $ "         ";y=6
         1 1 3 1 1 3 1 1 1 3 1 1 3 1 1          $ "         ";y=5
         1 1 1 1 1 1 1 3 1 1 1 1 1 1 1          $ "         ";y=4
         1 1 1 1 3 1 1 1 1 1 3 1 1 1 1          $ "         ";y=3
         1 1 3 1 1 1 1 1 1 1 1 1 3 1 1          $ "         ";y=2
         1 1 1 1 1 1 1 1 1 1 1 1 1 1 1          $ "         ";y=1
         1 1 1 3 1 1 1 3 1 1 1 3 1 1 1          $ "         ";y=0
         1 1 1 1 1 1 1 1 1 1 1 1 1 1 1          $ "         ":y=-1
         1 1 3 1 1 1 1 1 1 1 1 1 3 1 1          $ "         ";y=-2
         1 1 1 1 3 1 1 1 1 1 3 1 1 1 1          $ "         ";y=-3
         1 1 1 1 1 1 1 3 1 1 1 1 1 1 1          $ "         ";y=-4
         1 1 3 1 1 3 1 1 1 3 1 1 3 1 1          $ "         ";y=-5
         1 1 1 1 1 1 1 1 1 1 1 1 1 1 1          $ "         ";y=-6
         1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 imp:n=1 $ "         ";y=-7
c     Instrument/Control Rod Guide Tubes
26    4 -1.0     -10       24 -25       u=3 imp:n=1 $ water inside tube
27    3 -6.565 10 -11 24 -25       u=3 imp:n=1 $ Zr4 Clad
```

```
28    4 -1.0    11 16 -17 18 -19   24  -25 u=3 imp:n=1 $ Moderator
281   4 -1.0    (-16:17:-18:19)  24 -467 u=3 imp:n=1 $ Spacer - Moderator
282   3 -6.565 (-16:17:-18:19) 467 -466 u=3 imp:n=1 $ Zr4 - 2nd Spacer
283   4 -1.0    (-16:17:-18:19) 466 -465 u=3 imp:n=1 $ Spacer - Moderator
284   3 -6.565 (-16:17:-18:19) 465 -464 u=3 imp:n=1 $ Zr4 - 3rd Spacer
285   4 -1.0    (-16:17:-18:19) 464 -463 u=3 imp:n=1 $ Spacer - Moderator
286   3 -6.565 (-16:17:-18:19) 463 -462 u=3 imp:n=1 $ Zr4 - 4th Spacer
287   4 -1.0    (-16:17:-18:19) 462 -461 u=3 imp:n=1 $ Spacer - Moderator
288   3 -6.565 (-16:17:-18:19) 461 -460 u=3 imp:n=1 $ Zr4 - 5th Spacer
289   4 -1.0    (-16:17:-18:19) 460 -459 u=3 imp:n=1 $ Spacer - Moderator
290   3 -6.565 (-16:17:-18:19) 459 -458 u=3 imp:n=1 $ Zr4 - 6th Spacer
291   4 -1.0    (-16:17:-18:19) 458 -457 u=3 imp:n=1 $ Spacer - Moderator
292   3 -6.565 (-16:17:-18:19) 457 -456 u=3 imp:n=1 $ Zr4 - 7th Spacer
293   4 -1.0    (-16:17:-18:19) 456 -455 u=3 imp:n=1 $ Spacer - Moderator
294   3 -6.565 (-16:17:-18:19) 455 -454 u=3 imp:n=1 $ Zr4 - 8th Spacer
295   4 -1.0    (-16:17:-18:19) 454 -453 u=3 imp:n=1 $ Spacer - Moderator
296   3 -6.565 (-16:17:-18:19) 453 -452 u=3 imp:n=1 $ Zr4 - 9th Spacer
297   4 -1.0    (-16:17:-18:19) 452 -25  u=3 imp:n=1 $ Spacer - Moderator
c     Lower Tie Plate
c     Instrument/Control Rod Guide Tube Locations
29    4 -1.0    -10          -24 30     u=3 imp:n=1 $ water inside tube
30    3 -6.565 10 -11     -24 30     u=3 imp:n=1 $ Zr4 Clad
31    6 -8.03 11          -24 30     u=3 imp:n=1 $ 304L SS in LTP
c     Water below Lower tie plate/above channel bottom -below fuel pins
311   4 -1.0     -30                      u=3 imp:n=1 $ Water
c     Upper Tie Plate
c     Instrument/Control Rod Guide Tube Locations
33    4 -1.0    -10       25              u=3 imp:n=1 $ water inside tube
34    3 -6.565 10 -11 25              u=3 imp:n=1 $ Zr4 Clad
35    6 -8.03 11       25              u=3 imp:n=1 $ 304L SS in UTP
c     Fuel Assembly
36     0 12 -13 14 -15 26 -31 u=42 fill=2 trcl=132 imp:n=1 $ FA #2
363    0 12 -13 14 -15 26 -31 u=43 fill=2 trcl=133 imp:n=1 $ FA #3
364    0 12 -13 14 -15 26 -31 u=44 fill=2 trcl=134 imp:n=1 $ FA #4
365    0 12 -13 14 -15 26 -31 u=45 fill=2 trcl=135 imp:n=1 $ FA #5
366    0 12 -13 14 -15 26 -31 u=46 fill=2 trcl=136 imp:n=1 $ FA #6
367    0 12 -13 14 -15 26 -31 u=47 fill=2 trcl=137 imp:n=1 $ FA #7
c
c     Water Gap between fuel assembly and guide channel
c     and above UTP.
c
40    4 -1.0     (41 -42 45 -46 26)      u=4  imp:n=1    $ FA #1 - Center Hole
402   4 -1.0     (41 -42 45 -46 26) #36  u=42 imp:n=1    $ FA #2
403   4 -1.0     (41 -42 45 -46 26) #363 u=43 imp:n=1    $ FA #3
404   4 -1.0     (41 -42 45 -46 26) #364 u=44 imp:n=1    $ FA #4
405   4 -1.0     (41 -42 45 -46 26) #365 u=45 imp:n=1    $ FA #5
406   4 -1.0     (41 -42 45 -46 26) #366 u=46 imp:n=1    $ FA #6
407   4 -1.0     (41 -42 45 -46 26) #367 u=47 imp:n=1    $ FA #7
c
c     Guide Channel side & 1 in bottom plate (mixture of H2O & SS304)
41    13 -5.51326       #40  u=4   imp:n=1
412   13 -5.51326 #36   #402 u=42 imp:n=1
413   13 -5.51326 #363 #403 u=43 imp:n=1
414   13 -5.51326 #364 #404 u=44 imp:n=1
415   13 -5.51326 #365 #405 u=45 imp:n=1
416   13 -5.51326 #366 #406 u=46 imp:n=1
417   13 -5.51326 #367 #407 u=47 imp:n=1
c
c     Define a row of 6 Horizontal poison pins
c     First a pin with axial segments (poison, steel, poison, etc)
44    4 -1.0    -61      -301     u=5 imp:n=1 $ water below bottom B4C
45    10 -1.2225  -60 301 -302     u=5 imp:n=1 $ B4C reduced 75% - Pin 1
46    6 -8.03  60 -61 301 -302     u=5 imp:n=1 $ poison pin SS clad
461   6 -8.03      -61 302 -303     u=5 imp:n=1 $ Steel
462   10 -1.2225  -60 303 -304     u=5 imp:n=1 $ B4C reduced 75% - Pin 2
463   6 -8.03  60 -61 303 -304     u=5 imp:n=1 $ poison pin SS clad
464   6 -8.03      -61 304 -305     u=5 imp:n=1 $ Steel
465   10 -1.2225  -60 305 -306     u=5 imp:n=1 $ B4C reduced 75% - Pin 3
466   6 -8.03  60 -61 305 -306     u=5 imp:n=1 $ poison pin SS clad
```

```
467  6 -8.03      -61 306 -307     u=5 imp:n=1 $ Steel
468  10 -1.2225   -60 307 -308     u=5 imp:n=1 $ B4C reduced 75% - Pin 4
469  6 -8.03   60 -61 307 -308     u=5 imp:n=1 $ poison pin SS clad
470  6 -8.03      -61 308 -309     u=5 imp:n=1 $ Steel
471  10 -1.2225   -60 309 -310     u=5 imp:n=1 $ B4C reduced 75% - Pin 5
472  6 -8.03   60 -61 309 -310     u=5 imp:n=1 $ poison pin SS clad
473  6 -8.03      -61 310 -311     u=5 imp:n=1 $ Steel
474  10 -1.2225   -60 311 -312     u=5 imp:n=1 $ B4C reduced 75% - Pin 6
475  6 -8.03   60 -61 311 -312     u=5 imp:n=1 $ poison pin SS clad
476  6 -8.03      -61 312 -313     u=5 imp:n=1 $ Steel
477  10 -1.2225   -60 313 -314     u=5 imp:n=1 $ B4C reduced 75% - Pin 7
478  6 -8.03   60 -61 313 -314     u=5 imp:n=1 $ poison pin SS clad
479  6 -8.03      -61 314 -315     u=5 imp:n=1 $ Steel
480  10 -1.2225   -60 315 -316     u=5 imp:n=1 $ B4C reduced 75% - Pin 8
481  6 -8.03   60 -61 315 -316     u=5 imp:n=1 $ poison pin SS clad
482  6 -8.03      -61 316 -317     u=5 imp:n=1 $ Steel
483  10 -1.2225   -60 317          u=5 imp:n=1 $ B4C reduced 75% - Pin 9
484  6 -8.03   60 -61 317          u=5 imp:n=1 $ poison pin SS clad
c
49   4 -1.0     61             u=5 imp:n=1 $ water around pins
c     Fill the lattice
60   0 76 -77 72 -73  lat=1 fill= -2:3 0:0 0:0
                    5 5 5 5 5 5  u=55    imp:n=1
c     Define the horizontal row
61   0 48 -49 72 -73 30 -31  fill=55 trcl=20 imp:n=1   $ Horiz Above FA#1
c     Define the rest of the horizontal rows
62   like 61 but trcl=21 imp:n=1 $ Horiz below FA#2
63   like 61 but trcl=22 imp:n=1 $ Horiz below FA#3
64   like 61 but trcl=23 imp:n=1 $ Horiz above FA#4
65   like 61 but trcl=24 imp:n=1 $ Horiz above FA#5
66   like 61 but trcl=25 imp:n=1 $ Horiz below FA#4
67   like 61 but trcl=26 imp:n=1 $ Horiz below FA#1
68   like 61 but trcl=27 imp:n=1 $ Horiz below FA#5
69   like 61 but trcl=28 imp:n=1 $ Horiz above FA#6
70   like 61 but trcl=29 imp:n=1 $ Horiz above FA#7
c
c     Define a column of 6 Vertical poison pins
c     First a pin with axial segments (poison, steel, poison, etc)
74   4 -1.0     -63      -301     u=6 imp:n=1 $ water below bottom B4C
75   10 -1.2225  -62 301 -302     u=6 imp:n=1 $ B4C reduced 75% - Pin 1
76   6 -8.03  62 -63 301 -302     u=6 imp:n=1 $ poison pin SS clad
761  6 -8.03     -63 302 -303     u=6 imp:n=1 $ Steel
762  10 -1.2225  -62 303 -304     u=6 imp:n=1 $ B4C reduced 75% - Pin 2
763  6 -8.03  62 -63 303 -304     u=6 imp:n=1 $ poison pin SS clad
764  6 -8.03     -63 304 -305     u=6 imp:n=1 $ Steel
765  10 -1.2225  -62 305 -306     u=6 imp:n=1 $ B4C reduced 75% - Pin 3
766  6 -8.03  62 -63 305 -306     u=6 imp:n=1 $ poison pin SS clad
767  6 -8.03     -63 306 -307     u=6 imp:n=1 $ Steel
768  10 -1.2225  -62 307 -308     u=6 imp:n=1 $ B4C reduced 75% - Pin 4
769  6 -8.03  62 -63 307 -308     u=6 imp:n=1 $ poison pin SS clad
770  6 -8.03     -63 308 -309     u=6 imp:n=1 $ Steel
771  10 -1.2225  -62 309 -310     u=6 imp:n=1 $ B4C reduced 75% - Pin 5
772  6 -8.03  62 -63 309 -310     u=6 imp:n=1 $ poison pin SS clad
773  6 -8.03     -63 310 -311     u=6 imp:n=1 $ Steel
774  10 -1.2225  -62 311 -312     u=6 imp:n=1 $ B4C reduced 75% - Pin 6
775  6 -8.03  62 -63 311 -312     u=6 imp:n=1 $ poison pin SS clad
776  6 -8.03     -63 312 -313     u=6 imp:n=1 $ Steel
777  10 -1.2225  -62 313 -314     u=6 imp:n=1 $ B4C reduced 75% - Pin 7
778  6 -8.03  62 -63 313 -314     u=6 imp:n=1 $ poison pin SS clad
779  6 -8.03     -63 314 -315     u=6 imp:n=1 $ Steel
780  10 -1.2225  -62 315 -316     u=6 imp:n=1 $ B4C reduced 75% - Pin 8
781  6 -8.03  62 -63 315 -316     u=6 imp:n=1 $ poison pin SS clad
782  6 -8.03     -63 316 -317     u=6 imp:n=1 $ Steel
783  10 -1.2225  -62 317          u=6 imp:n=1 $ B4C reduced 75% - Pin 9
784  6 -8.03  62 -63 317          u=6 imp:n=1 $ poison pin SS clad
c
79   4 -1.0     63             u=6 imp:n=1 $ water around pins
c    Fill the lattice
80   0 76 -78 79 -791  lat=1 fill=6  u=66    imp:n=1
```

```
c     Define the vertical column
81    0 44 -47 74 -75 30 -31  fill=66 trcl=30 imp:n=1   $ Vert Right of FA#2
c     Define the rest of the vertical columns
85    like 81 but trcl=31 imp:n=1 $ vert left of FA#3
86    like 81 but trcl=32 imp:n=1 $ vert rght of FA#4
87    like 81 but trcl=33 imp:n=1 $ vert left of FA#1
88    like 81 but trcl=34 imp:n=1 $ vert rght of FA#1
89    like 81 but trcl=35 imp:n=1 $ vert left of FA#5
90    like 81 but trcl=36 imp:n=1 $ vert rght of FA#6
91    like 81 but trcl=37 imp:n=1 $ vert left of FA#7
c
c     Make a dummy water FA in the center
c
42     0  40 -43 44 -47 27 -33 fill=4 imp:n=1
c
c     Define the 6 Outer FAs
c     Make a unit out of the FA, water gap, and guide channel
c
100    0  40 -43 44 -47 27 -33 fill=42 trcl=121  imp:n=1 $ FA #2
101    0  40 -43 44 -47 27 -33 fill=43 trcl=122  imp:n=1 $ FA #3
102    0  40 -43 44 -47 27 -33 fill=44 trcl=123  imp:n=1 $ FA #4
103    0  40 -43 44 -47 27 -33 fill=45 trcl=124  imp:n=1 $ FA #5
104    0  40 -43 44 -47 27 -33 fill=46 trcl=125  imp:n=1 $ FA #6
105    0  40 -43 44 -47 27 -33 fill=47 trcl=126  imp:n=1 $ FA #7
c
c     Define the 4 basket support rods
106   6 -8.03 -80 27 -33       imp:n=1  $ Upper left
107   6 -8.03 -81 27 -33       imp:n=1  $ Upper right
108   6 -8.03 -82 27 -33       imp:n=1  $ Lower left
109   6 -8.03 -83 27 -33       imp:n=1  $ Lower right
c
c    Define Cask Cells
c
200   6 -8.03  27 -203 100 -101 imp:n=1 $ 317 SS Inner Shell - Radial
201   6 -8.03  202 -27     -101 imp:n=1 $ 304 SS Inner Shell - Bottom
202   6 -8.03  203 -204    -101 imp:n=1 $ 304 SS Inner Shell - Top
203   11 -18.82 (-102 201 -202):(101 -102 202 -204):(-102 204 -205)
                 imp:n=1 $ Lead (union of bottom/side/top)
204   6 -8.03 (-103 200 -201):(102 -103 201 -205):(-103 205 -206)
           imp:n=1 $ 304 SST outer shell (union of bottom/side/top)
c
c     Water outside FAs in basket and inside Cask.
c
1000  4 -1.0        -100 27 -203 51 #100 #101 #62 #63 #81 #85 #106 #107
                             imp:n=1 $ FAs 2&3 Surrounded by water
1001  4 -1.0     -100 27 -203 50 -51 #42 #102 #103
             #61 #64 #65 #66 #67 #68 #86 #87 #88 #89
                             imp:n=1 $ FAs 1,4,5 Surrounded by water
1002  4 -1.0     -100 27 -203 -50 #104 #105 #69 #70 #90 #91 #108 #109
                             imp:n=1 $ FAs Surrounded by water
c
c     1 cm water reflector
c     Water around cask
c
2000  4 -0.0001    (-52 53 -54 55 -56 57 58 -59) (206:-200:103) imp:n=1
c
2001  0      (52:-53:54:-55:56:-57:-58:59)  imp:n=0

c
c     Fuel Cell
c
1     cz  .45339   $ Fuel Pellet OD
2     cz  .46228   $ Zr4 Clad ID
3     cz  .53848   $ Zr4 Clad OD
4     px -0.71501  $ fuel rod cell boundary
5     px  0.71501  $ fuel rod cell boundary
6     py -0.71501  $ fuel rod cell boundary
7     py  0.71501  $ fuel rod cell boundary
c
```

```
c     Instrument Tube/Control Rod Guide Tube
c
10    cz  0.64897  $ ID
11    cz  0.69088  $ OD
c
c     Fuel Assembly
c
12    px -10.7137  $ 1/2 FA pitch
13    px  10.7137  $ 1/2 FA pitch
14    py -10.7137  $ 1/2 FA pitch
15    py  10.7137  $ 1/2 FA pitch
c
c     Zr grid inner pitch
c
16    px -0.712475 $ Zr grid cell boundary
17    px  0.712475 $ Zr grid cell boundary
18    py -0.712475 $ Zr grid cell boundary
19    py  0.712475 $ Zr grid cell boundary
c
c     Overall Fuel Height including blanket - 144 inches
c
20    pz -182.88
21    pz  182.88
c
c     Axial Blanket/enriched fuel zone - 6 inches below top & bottom
c
22    pz -167.64
23    pz  167.64
c
c     Top and bottom plenum regions
c
24    pz -185.75
25    pz  204.673
c
c     Channel bottom plate
c
26    pz -192.151
27    pz -194.691
c
c   Lower Tie Plate - use FA px/py (8.424 in pitch vs 8.436 in for FA)
c
c     Smear mass over rectangle for now
c     Bottom of LTP
30    pz -186.953      $ Water to bottom of lowest poison pin B4C
c  Surfaces for poison pin/steel segments
301   pz -178.65725    $ Poison in lowest poison pin to steel
302   pz -138.85545    $ Steel to bottom of next poison pin B4C
303   pz -125.8062     $ Poison in next poison pin to steel
304   pz  -91.8718     $ Steel to bottom of next poison pin B4C
305   pz -78.82255     $ Poison in next poison pin to steel
306   pz -44.88815     $ Steel to bottom of next poison pin B4C
307   pz -31.8389      $ Poison in next poison pin to steel
308   pz   2.0955      $ Steel to bottom of next poison pin B4C
309   pz  15.14475     $ Poison in next poison pin to steel
310   pz  49.07915     $ Steel to bottom of next poison pin B4C
311   pz  62.1284      $ Poison in next poison pin to steel
312   pz  96.0628      $ Steel to bottom of next poison pin B4C
313   pz 109.11205     $ Poison in next poison pin to steel
314   pz 143.04645     $ Steel to bottom of next poison pin B4C
315   pz 156.0957      $ Poison in next poison pin to steel
316   pz 190.0301      $ Steel to bottom of top poison pin B4C
317   pz 203.07935     $ Poison in top poison pin to steel - through UTP
c
c    Upper Tie Plate - use FA px/py (8.424 in pitch vs 8.436 in for FA)
c
c     Smear mass over rectangle for now
c     Top of UTP
31    pz 206.538
c
```

```
33    pz 213.512  $ Top of FA
c
c     Square Cell for Channel
c
40    px  -11.3816
41    px  -11.1919
42    px   11.1919
43    px   11.3816
44    py  -11.3816
45    py  -11.1919
46    py   11.1919
47    py   11.3816
c
c     Rectangular Cell for Basket (ignore 9 - 1" thick axial spacers)
c
48    px  -11.43
49    px   11.43
50    py  -13.0548
51    py   13.0548
c
c     Hexagonal Cell Surrounding Cask for Infinite array
c
c       inner hex surfaces bounding lattice, (n-0.5)*p*cos30
*52   p    0.8660254   -0.5   0.0     64.000
*53   p    0.8660254   -0.5   0.0    -64.000
*54   p    0.8660254    0.5   0.0     64.000
*55   p    0.8660254    0.5   0.0    -64.000
*56   py   64.000
*57   py  -64.000
*58   pz    -212.201  $  2 cm bottom pitch
*59   pz     252.079  $  2 cm top pitch
c
c     B4C poison pins -
60   c/z 1.905   0.8763 0.5842    $ ID of SS304 clad
61   c/z 1.905   0.8763 0.635     $ OD of SS304 clad
62   c/z 1.1049  1.905  0.5842    $ ID of SS304 clad
63   c/z 1.1049  1.905  0.635     $ OD of SS304 clad
72   py 0.0397  $
73   py 1.7129  $ 1/2 pitch for horiz poison pin row (1/2 of 1.38 in)
74   px 0.0397  $
75   px 2.3352  $ 1/2 pitch for vertic poison pin row (1/2 of 1.87 in)
76   px 0.0      $ 1/2 x dimension pitch for poison pin row
77   px 3.81
78   px 2.2098
79   py 0.0
791  py 3.81
c
c    Four Basket Support Rods - 2-1/4 inch 216 SS
c
80   c/z -29.21  26.43124  2.8575
81   c/z  29.21  26.43124  2.8575
82   c/z -29.21 -26.43124  2.8575
83   c/z  29.21 -26.43124  2.8575
c
c    Cask dimensions
c
c    Radial
100  cz    47.625   $ Inner Cavity -18.75"
101  cz    48.895   $ 317 SS inner - 0.5"
102  cz    59.055   $ Cast DU      - 4"
103  cz   63.0174   $ 317 SS outer -1.56"
104  cz   68.0174   $ 5 cm side reflector
105  cz   93.4974   $ 12 inch side reflector
c    Axial - Bottom to Top of Cask
200  pz -211.201    $ 304 SST  - 1.5"
201  pz -207.391    $ Cast DU  - 3.75"
202  pz -197.866    $ 304 SST  - 1.25"
203  pz  235.839    $ Cavity  -169.5"
204  pz  238.379    $ 304 SST - 1"
```

```
205  pz  245.999    $ Cast DU - 3"
206  pz  251.079    $ 304 SST - 2"
c
c  Axial planes for spacer grid
c
450    pz   199.3265 $ Top of top spacer
451    pz   194.8815
452    pz   152.0063
453    pz   147.5613
454    pz   117.4115
455    pz   115.5065
456    pz   85.4837
457    pz   81.0387
458    pz   50.8889
459    pz   48.9839
460    pz   18.9611
461    pz   14.5161
462    pz   -15.6337
463    pz   -17.5387
464    pz   -47.5615
465    pz   -52.0065
466    pz   -114.0841
467    pz   -118.5291
468    pz   -174.9552
469    pz   -180.6702  $ 1st spacer from bottom
1000 so 1000

c     Translations for horizontal row of 6 poison pins
tr1    -9.525  0.8763   0    $ Left
tr2    -5.715  0.8763   0    $
tr3    -1.905  0.8763   0    $
tr4     1.905  0.8763   0    $
tr5     5.715  0.8763   0    $
tr6     9.525  0.8763   0    $ Right
c     Translations for vertical row of 6 poison pins
tr11    1.18745 -9.525  0     $ Bottom
tr12    1.18745 -5.715  0     $
tr13    1.18745 -1.905  0     $
tr14    1.18745  1.905  0     $
tr15    1.18745  5.715  0     $
tr16    1.18745  9.525  0     $ Top
c     Translate horizontal poison pin rows
tr20      0.0000  11.3419     0 $ Horiz above FA#1
tr21    -13.6771  13.0151     0 $ Horiz below FA#2
tr22     13.6771  13.0151     0 $ Horiz below FA#3
tr23    -27.3542  11.3419     0 $ Horiz above FA#4
tr24     27.3542  11.3419     0 $ Horiz above FA#5
tr25    -27.3542 -13.0945     0 $ Horiz below FA#4
tr26      0.0000 -13.0945     0 $ Horiz below FA#1
tr27     27.3542 -13.0945     0 $ Horiz below FA#5
tr28    -13.6771 -14.7677     0 $ Horiz above FA#6
tr29     13.6771 -14.7677     0 $ Horiz above FA#7
c     Translate vertical poison pin rows
tr30     -2.3352  26.1096   0 $ vert rght of FA#2
tr31     -0.0397  26.1096   0 $ vert left of FA#3
tr32    -16.0123   0.0000   0 $ vert rght of FA#4
tr33    -13.7168   0.0000   0 $ vert left of FA#1
tr34     11.3419   0.0000   0 $ vert rght of FA#1
tr35     13.6374   0.0000   0 $ vert left of FA#5
tr36     -2.3352 -26.1096   0 $ vert rght of FA#6
tr37     -0.0397 -26.1096   0 $ vert left of FA#7
c     FA translations
tr121   -13.6771 26.1096   0    $ FA #2
tr122    13.6771 26.1096   0    $ FA #3
tr123   -27.3542 0         0    $ FA #4
tr124    27.3542 0         0    $ FA #5
tr125   -13.6771 -26.1096  0    $ FA #6
tr126    13.6771 -26.1096  0    $ FA #7
c     Shift FA within basket channel
```

```
tr132 -0.478  0.478 0    $ FA #2
tr133  0.478  0.478 0    $ FA #3
tr134 -0.478  0      0    $ FA #4
tr135  0.478  0      0    $ FA #5
tr136 -0.478 -0.478 0    $ FA #6
tr137  0.478 -0.478 0    $ FA #7
mode n
kcode  3000 1 30 240 50000
print -128
prdmp j -120 j 3
fc4   fission * lethargy**2 in cell 1
f4:n   1
fm4    -1  1  -6
sd4    1.0
c     lethargy**2 [base 20 MeV -- u=0 at 20 MeV]
de4   1.e-8 1.e-7 1.e-6 1.e-5 1.e-4 .001   .01    .1     1    10    14
df4   458.7 365.3 282.6 210.5 149.0 98.08 57.77 28.07 8.974 0.48 .127
fc14  fission in cell 1
f14:n  1
fm14   -1 1 -6
sd14   1.0
fc24   fission * lethargy in cell 1
f24:n   1
fm24    -1  1  -6
sd24    1.0
c     lethargy [base 20 MeV -- u=0 at 20 MeV]
de24  1.e-8 1.e-7 1.e-6 1.e-5 1.e-4 .001 .01    .1      1   10     14
df24  21.42 19.11 16.81 14.51 12.21 9.90 7.60 5.298 2.996 0.693 0.357
c     m1 is UO2 fuel - Enriched to 4.25 wt% U235
m1    92235.50c  -0.037462
      92238.50c  -0.843989
      8016.50c   -0.118549
c     m2 is He
m2    2004.50c -1.0
c     m3 is Zircaloy 4
m3    40000.60c  -98.18
      8016.50c    -0.12
      24000.50c   -0.10
      26000.55c   -0.20
      50000.35c   -1.40
c     m4 is water
m4    1001.50c 0.666700 8016.50c 0.333300
c     m5 is Natural UO2 blanket fuel - 0.72 wt% U235
m5    92235.50c -0.0062672
      92238.50c -0.875206
      8016.50c  -0.118528
c     m6 is 304L SS
m6    6000.50c      -0.03
      14000.50c        -1
      15031.50c    -0.045
      16032.50c     -0.03
      24000.50c       -20
      25055.50c        -2
      26000.55c   -64.895
      28000.50c       -12
c     m7 is Inconel 718
m7    5000.01c     -0.006
      6000.50c      -0.08
      13027.50c      -0.8
      14000.50c     -0.35
      22000.50c     -1.15
      24000.50c       -21
      25055.50c     -0.35
      26000.55c   -11.164
      27059.50c        -1
      28000.50c       -55
      29000.50c      -0.3
      41093.50c      -5.5
      42000.50c      -3.3
```

```
c     m8 is Inconel X750
m8    6000.50c   -0.08
      13027.50c     -1
      14000.50c   -0.5
      22000.50c  -2.75
      24000.50c    -15
      25055.50c     -1
      26000.55c     -7
      27059.50c     -1
      28000.50c    -70
      29000.50c   -0.5
      41093.50c   -1.2
c     m10 is B4C poison
m10   5010.50c  -0.140886  $ B10 lower end 18.3% - 0.3%
      5011.50c  -0.641812  $ B11 upper end 81.7% + 0.3%
      6000.50c  -0.217302  $ C
c     m11 is Depleted Uranium
m11   92235.50c 0.000106128
      92238.50c 0.0475275
c     m12 is Air
m12   7014.50c -0.765
      8016.50c -0.235
c     m13 is Channel - 304 SS and water mixture (VF water = 0.358)
m13   1001.50c   -0.007266
      6000.50c   -0.000748
      8016.50c   -0.057669
      14000.50c  -0.009351
      15031.50c  -0.000421
      16032.50c  -0.000281
      24000.50c  -0.187013
      25055.50c  -0.018701
      26000.55c  -0.620369
      28000.50c  -0.098182
mt4   lwtr.01t
mt13  lwtr.01t
```