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Title COMMERCIAL REACTOR REACTIVITY ANALYSIS FOR GRAND GULF, UNIT 1

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PURPOSE AND SUMMARY OF RESULTS:

Purpose: The purpose of this calculation is to document the Grand Gulf, Unit 1 (GG1), Critical statepoints reactivity calculations using the MCNP computer code.

Summary: The sixteen critical statepoints for the Grand Gulf unit 1 reactor have been calculated using the half core geometry that was developed for the MCNP code. The k-effectives calculated varied from 0.966 to 0.998 for the critical statepoints.

Note: Document reviewed by
L.A. Hassler & T.N. Ake
LAH TNA

THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:

CODE/VERSION/REV	CODE/VERSION/REV
MCNP, VERSION 4B2L	

THE DOCUMENT CONTAINS ASSUMPTIONS THAT MUST BE VERIFIED PRIOR TO USE ON SAFETY-RELATED WORK

☐ YES ☒ NO

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1. PURPOSE

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The objective of this calculation is to document the Grand Gulf Unit 1 (GG1) reactivity calculations for sixteen critical statepoints in cycles 4 through 8. The GG1 reactor is a boiling water reactor (BWR) owned and operated by Entergy Operations Inc. The Commercial Reactor Criticality (CRC) evaluations support the development and validation of the neutronic models used for criticality analyses involving commercial spent nuclear fuel to be placed in a geologic repository. This calculation is performed as part of the evaluation in the CRC program.

This report is an engineering calculation supporting the burnup credit methodology of Yucca Mountain Project (YMP) 2000 (Reference 5) and was performed under Framatome ANP Administrative Procedure 0402-01, Preparing and Processing FANP Calculations (Reference 4) and Framatome Quality Management Manual (Reference 8).

2. METHOD

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The calculational method used to perform the reactivity analysis calculations consists of using the three dimensional MCNP Monte Carlo neutron transport computer code (Reference 1) to analyze the 16 measured critical condition statepoints that occurred in cycles 4 through 8 for the GG1 reactor. The geometry used in the MCNP code was developed to analyze the GG1 reactor using half core symmetric geometry. Each fuel assembly input into the MCNP code has been depleted through its unique operating histories in Reference 2 for each of ten axial nodes in the assemblies. The fuel isotopic data were calculated at the 16 specific measured zero power critical points in cycles 4 through 8 of GG1 for each of the ten axial nodes in each of the 106 fuel assemblies followed in one-eighth core. Each fuel assembly depletion calculation was based on detailed core follow information found in Reference 3.

3. ASSUMPTIONS

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The following assumptions were used for all reactivity calculations.

3.1 It is assumed that half-core symmetry adequately approximates the fuel loading of the core and also adequately represents the control blade insertion for the core. The fuel assembly information was tabulated for only one-eighth of the core. The fuel for the one-eighth can be expanded to half core and will adequately represent the average of the full core. The reason for setting up the half core geometry is to better model the non-symmetrical use of the control blades in the GG1 reactor. This assumption is used throughout this engineering calculation.

3.2 It is assumed that the water density throughout the core is uniform. This is not exact since the burned fuel is thermally hot and will cause small local temperature and density gradients. Because of the large reactor flow rate, these local gradients will be small and tend to average out and the error will be insignificant. This assumption is used throughout this engineering calculation.

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3.3 The stainless steel components between the core shroud and the inner surface of the pressure vessel including the jet pumps are neglected. This is acceptable because neutron importance in this region is extremely small. This assumption is used throughout this engineering calculation.

3.4 The structural components above and below the active fuel including the upper and lower tie plates, core grid and core support plate are homogenized with the moderator to represent these regions for neutron reflection purposes. These regions have little impact on the reactivity calculations. The moderator in the homogenized material is the most important component for the reflection of neutrons back into the core and the homogenized material is adequate for this purpose.

3.5 The fuel assembly spacer grids have been omitted from the calculations because they occupy a small volume and being made from zircaloy will have very small effects on the reactivity calculations.

3.6 Generic or standard Gadolinia (Gad) fuel rod locations for the 9x9 assemblies were taken from Reference 12 for 8, 9, and 10 Gad rods per assembly and locations in the fuel assembly are shown in Figures 31 to 33. Generic patterns must be used in the calculations because of the proprietary nature of Gad rod locations in an assembly. A generic set of Gad rod locations were then developed for the 8x8 fuel assemblies based on the standard patterns used in the 9x9 assemblies. The 8x8 assemblies use 5, 6, or 8 Gad rods per assembly and the generic patterns are shown in Figures 34 to 36. When the Gad fuel is missing for one axial node or more in a single fuel rod, the pattern with one less Gad rod is used. This could cause a change in the Gad rod pattern for those nodes. Tables 21 to 27 give the number of Gad rods for all the different fuel types for each of the 10 axial nodes. The reactivity in the assembly and finally in the core is more dependent on the number of Gad rods than their location within the assembly. This assumption of using standard Gad rod placement by node is considered to introduce negligible error in the results.

3.7 The large diameter fuel rods and the smaller diameter fuel rods in the 9x9 assemblies were volume averaged to give a single diameter fuel rod that was used in the calculations. Since the quantity of fuel in the assembly is preserved, the assembly reactivity will not be affected significantly.

4. USE OF COMPUTER CODES

The calculations in this file are performed using the computer program MCNP (Reference 1) version 4B21 to calculate the K_{eff} for the GG1 reactor at specific statepoints. The computer code has been certified according to Framatome ANP procedure 0902-06 (Reference 9).

5. REACTOR DESCRIPTION

Grand Gulf Unit 1 (GG1) is a General Electric boiling water reactor with a rated power of 3833 MWt (Reference 3, p. 2-1). The reactor cores for Cycle 4 through 8 consisted of a mixture of eight hundred 8x8 and 9x9 fuel assemblies in each cycle. The MCNP analyses in this file modeled the lower half of the core or 400 fuel assemblies. Figure 1 shows the lower right

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quarter core arrangement of fuel assemblies and also gives the available control blade locations. The other lower left quarter of the modeled core is mirror symmetrical to Figure 1. The cylindrical shroud and pressure vessel surround the fuel assemblies array as seen in Figure 2. Table 1 gives a description of the sixteen statepoint configurations that were analyzed. Figure 3 from Reference 3 shows a typical array of four 8x8 fuel rod assemblies or bundles clustered around a control blade and Figure 4 from Reference 3 shows a typical BWR control blade. The 8x8 fuel assemblies are replaced starting in cycle 5 (see Tables 7 and 8) with fresh fuel assemblies that have 9x9 fuel rod arrays. The 9x9 fuel rod assemblies have the same outer dimensions and occupy the same space as the 8x8 assemblies but have smaller fuel rod diameters and a smaller fuel rod pitch within the assembly.

Each state-point is represented at a specific time in which the reactor goes critical and the power level is zero. At these critical conditions, the effective multiplication factor (k_{eff}) for the core was measured to be equal to 1.00. The CRC reactivity evaluation for each of the critical state-points involves the use of the MCNP code to calculate the core k_{eff}. The objective of each CRC state-point evaluation is to determine how close the developed MCNP model predicts the measured reactor core k_{eff}. The depletion calculations performed in Reference 2 provides the depleted fuel and burnable poison isotopic compositions that are used in the CRC reactivity calculations (MCNP) reported in this report.

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Table 1. GG1 Critical Configuration at Statepoints

Statepoint	Date (mo./day/yr.)	Shutdown History [a] (hours)	Burnup (MWd/MTU)	EFPD	Moderator Temperature (°F)	Moderator Density [b] g/cm^3
Cycle 4						
SP5	4/28/89	994	0	0	148.5	0.98897
SP6	5/31/89	425	109	4.01	188	0.97393
SP7	8/22/89	205	1998	73.49	221	0.96018
Cycle 5						
SP10	11/24/90	1340	0	0	111	1.00191
SP11	12/30/90	273	451	16.54	180	0.97710
SP12	5/23/91	114	4042	148.27	225.5	0.95823
SP13	6/15/91	85	4506	165.29	209	0.96531
SP14	8/04/91	185	5550	203.58	174	0.97944
SP15	1/08/92	247	9280	340.41	140	0.99201
Cycle 6						
SP16	6/04/92	1160	0	0	136	0.99342
Cycle 7						
SP18	11/26/93	1440	0	0	121	0.99858
SP19	4/01/94	139	2970	108.81	406.5	0.85967
SP20	8/27/94	93	6689	245.05	293	0.92622
Cycle 8						
SP21	6/09/95	1348	0	0	140	0.99201
SP22	6/13/95	91	0	0	178	0.97788
SP23	7/16/95	106	480	17.59	229	0.95669

Reference 3, Table 4-372, p.4-538

NOTE: [a] Shutdown History is time in hours prior to Statepoints.

[b] Moderator density is calculated using data from Reference 15 at the given temperature and at 1000 psia pressure which is slightly below the full power operating pressure of 1044 psia given in Tables 3 and 4.

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Figure 1. GG1 Assembly and Control Blade Group Locations ✓

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J	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
17	A1	B2	B2	A1	A1	B2	B2	A1	A1	B2	B2	A1	A1	B2	B2	NB
18	B1	A2	A2	B1	B1	A2	A2	B1	B1	A2	A2	B1	B1	A2	A2	NB
19	B1	A2	A2	B1	B1	A2	A2	B1	B1	A2	A2	B1	B1	A2	A2	
20	A1	B2	B2	A1	A1	B2	B2	A1	A1	B2	B2	A1	A1	B2	B2	
21	A1	B2	B2	A1	A1	B2	B2	A1	A1	B2	B2	A1	A1	B2	B2	
22	B1	A2	A2	B1	B1	A2	A2	B1	B1	A2	A2	B1	B1	A2	A2	
23	B1	A2	A2	B1	B1	A2	A2	B1	B1	A2	A2	B1	B1	A2	A2	
24	A1	B2	B2	A1	A1	B2	B2	A1	A1	B2	B2	A1	A1	NB		
25	A1	B2	B2	A1	A1	B2	B2	A1	A1	B2	B2	A1	A1			
26	B1	A2	A2	B1	B1	A2	A2	B1	B1	A2	A2	B1	B1			
27	B1	A2	A2	B1	B1	A2	A2	B1	B1	A2	A2	B1	B1			
28	A1	B2	B2	A1	A1	B2	B2	A1	A1	B2	B2	NB				
29	A1	B2	B2	A1	A1	B2	B2	A1	A1	B2	B2					
30	B1	A2	A2	B1	B1	A2	A2	NB								
31	B1	A2	A2	B1	B1	A2	A2									
32	NB	NB														

Reference 3, Figure 4-1, p.4-423

Note: NB indicates Assemblies with No Control Blade on any Corner.

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Figure 2. GG1 Quarter Core Diagram with Vessel and Shroud

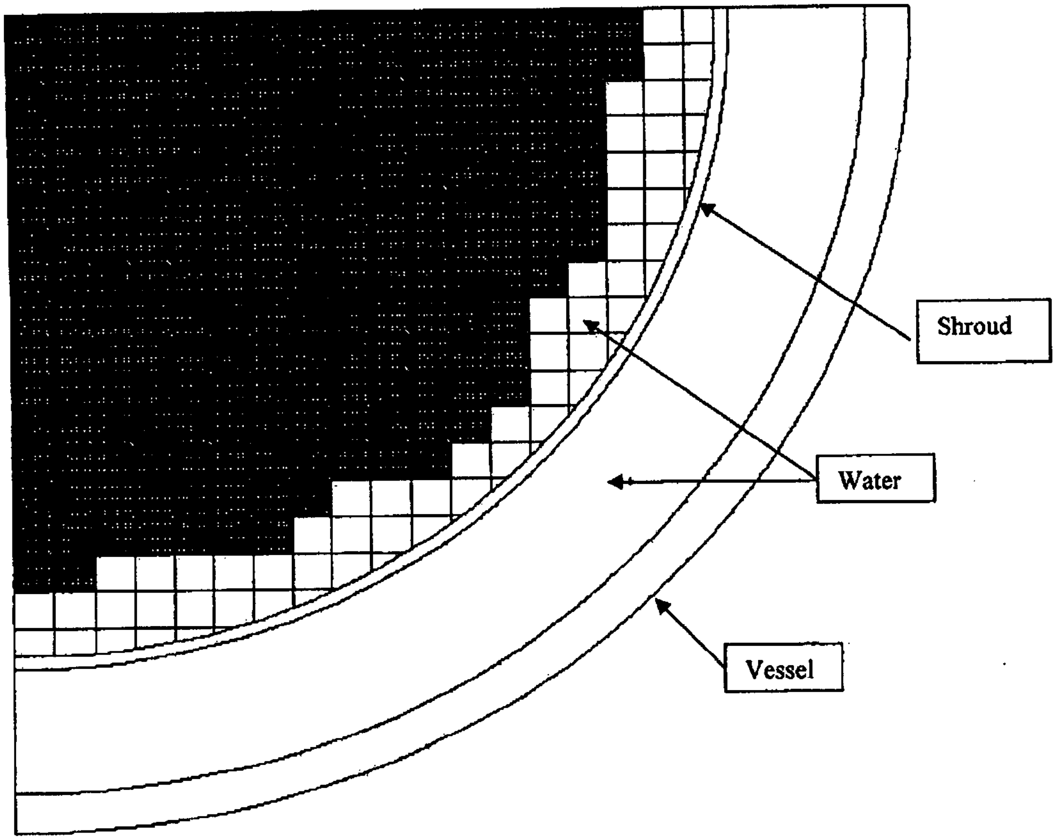

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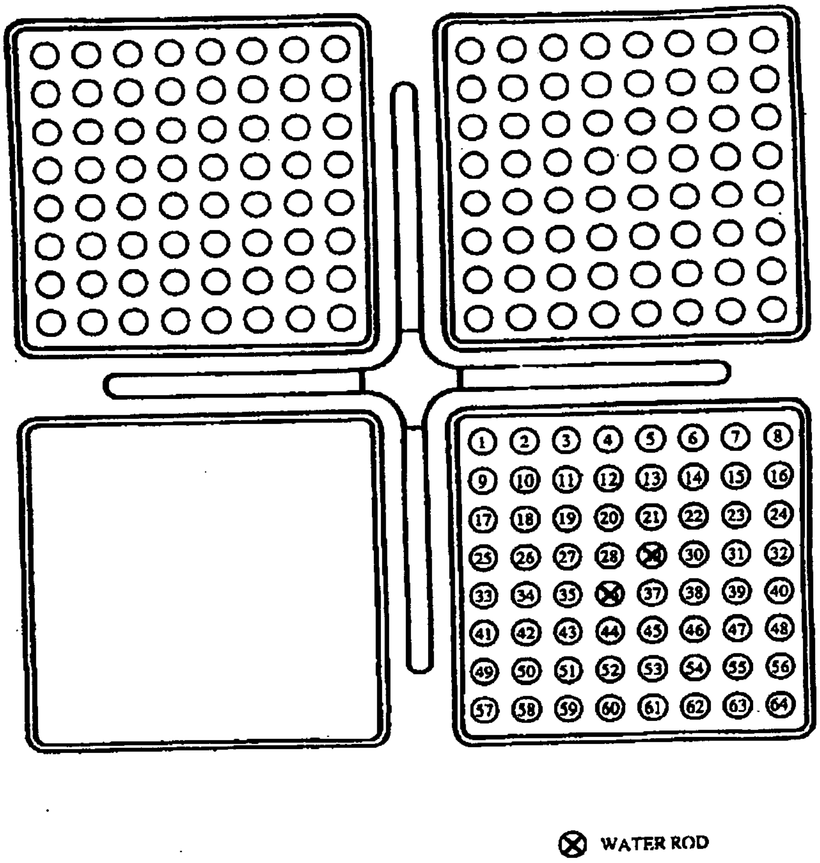
Figure 3. GG1 Typical Core Cell for 8x8 Fuel Array



Reference 3, Figure 2-1, p.2-2

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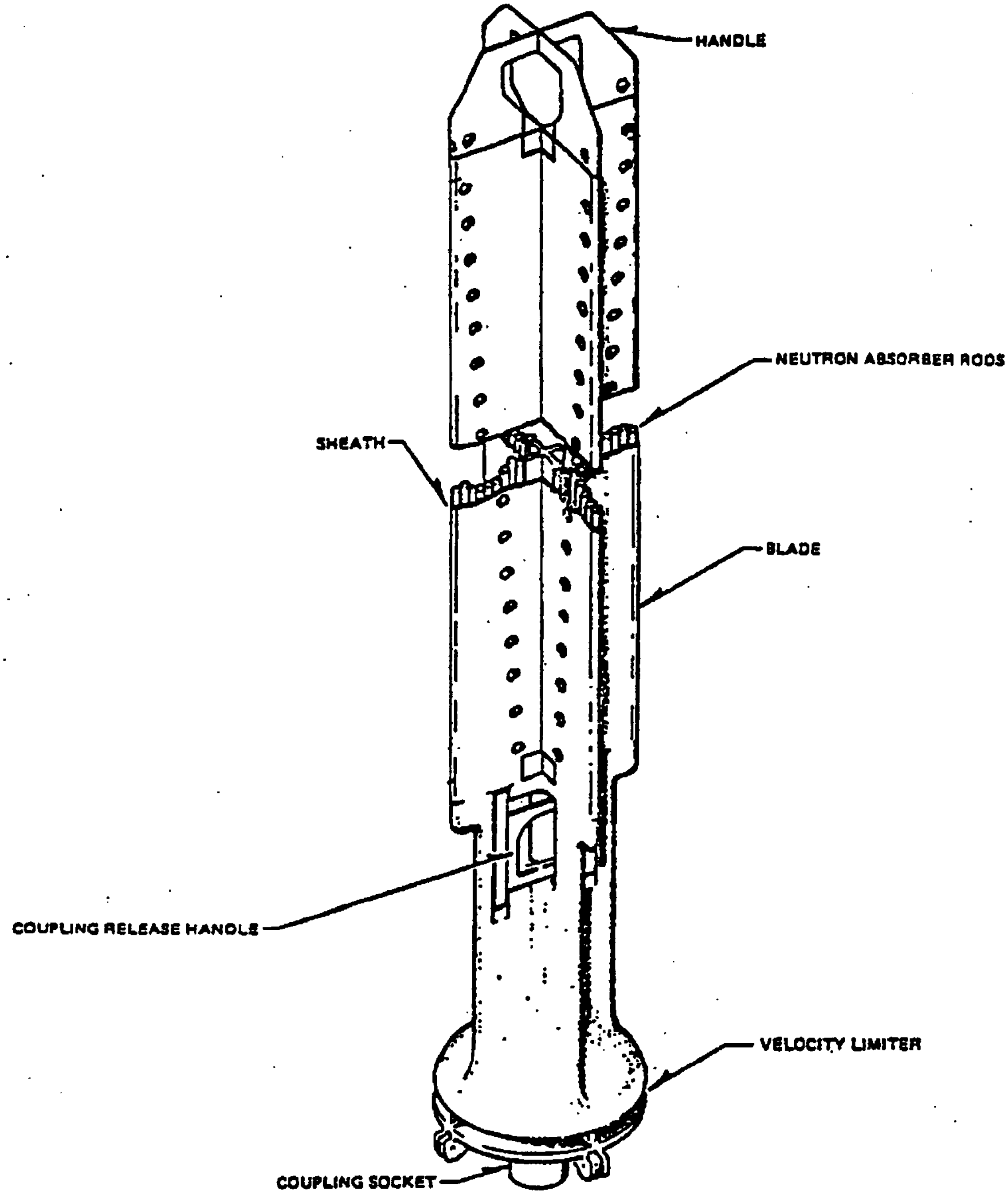
Figure 4. Typical BWR Control Blade



Reference 3, Figure 2-2, p.2-3

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5.1 REACTOR AND ASSEMBLY DESIGN INFORMATION FOR GG1

The GG1 statepoint reactivity calculations require the depletion of fuel assemblies for thirteen different fuel batches. The fuel design characteristics vary between each fuel batch. These different fuel batches were referred to in References 2 and 3 and in this file as assembly types A, B, C, D, E, F , G, H, J, K, L, M, and N. Assembly types A, B, C, and D use 8x8 array of fuel rods while all the remaining types are 9x9 arrays.

The information documented in this section describes the design specifications needed to construct the MCNP geometrical model for the reactor and fuel assemblies required for the Grand Gulf Unit 1 CRC evaluations and gives the specifications that were used in Reference 2 to deplete the fuel assemblies to obtain the fuel isotopics used in this analysis. The reactor and fuel assembly input specifications that were obtained from the Grand Gulf site are considered qualified data. All non-proprietary information was placed into Reference 3. This data was developed in accordance with an approved quality assurance program that meets the requirements of the Code of Federal Regulations (CFR) 60 Subpart G. All data given in this report was taken from Reference 3 unless otherwise noted. Applicable data for each of the thirteen different fuel types is provided in this section.

Reactivity control in the GG1 reactor is accomplished by a combination of cruciform control blades and integral burnable absorbers (Gadolinia bearing fuel rods). The control blades contain a stainless steel clad boron carbide (B_4C) absorber material and the integral burnable absorbers were located in the Gadolinia-bearing fuel rods (Gd_2O_3-UO_2). The 193 movable control blades are used in the reactivity control system to control the fission rate and fission density. The Gadolinia burnable absorber material was placed at different axial nodes and radial fuel pin locations (see Tables 21 to 27) throughout the fuel assembly and is used to balance reactivity effects in fresh and partially burned fuel. Figures 31 to 36 give the Gadolinia rod positions within the fuel assemblies for the different number of Gad rods in an assembly.

General fuel assembly information for each of the thirteen fresh fuel batches placed in cycles 2 through 8 is provided in Table 2 through 10. Cycles 2 and 3 fresh fuel assembly information are included because they are still in the reactor during the depletion of cycles 4 and 5 and are needed for input into the statepoint calculations occurring in cycles 4 and 5. Table 2 (Reference 3, p. 3-1) gives the fuel assembly type and the assembly average enrichment for each fuel batch. Tables 3 and 4 (Reference 3, p. 2-5 and p. 2-6) provide general core and operation information needed to construct the MCNP input decks. Table 5 contains the design data for the control blades. Tables 6 through 10 give design information on fuel enrichments, fuel densities, and fuel rod dimensions for all the fuel batches that will be used to perform the statepoint reactivity analyses.

The fuel rod enrichments and dimensions were averaged to give one size fuel rod and a single fuel enrichment for each fuel type. The 9x9 fuel types (E through N) have some large diameter rods and some smaller diameter fuel rods. These two size rods were averaged and only one size rod was used in the calculations. The Gadolinia bearing rods were separate from the non-Gad

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bearing rods. Both Gad and non-Gad rods had the same smeared fuel enrichment but only the Gad rods contained the burnable absorber.

Table 2. GG1 Fuel Batch General Description for Cycles 2 through 8

Cycle	Assembly Number	Fuel Type Designation	Fuel Batch Type	Average wt% ^{235}U
2	1	A	ENC8x8	2.81
3	2	B	ANF8x8	3.01
	3	C	ANF8x8	3.01
4	4	D	ANF8x8	3.37
	5	E	LTA9x9-5	3.25
5	6	F	ANF9x9-5	3.42
	7	G	ANF9x9-5	3.42
6	8	H	ANF9x9-5	3.38
	9	J	ANF9x9-5	2.94
7	10	K	SNP9x9-5	3.42
	11	L	SNP9x9-5	3.20
8	12	M	SNP9x9-5	3.07
	13	N	SNP9x9-5	3.56

Reference 3, p.3-1

Table 3. GG1 Reactor Core and Vessel Design Information

General Description	Dimension
Total number of assemblies	800
Number of fuel rods per assembly	62 or 76
Number of water rods	2 or 5
Channel	13.246 cm wide, 0.3048 cm thick
Assembly pitch	15.24 cm
Pin pitch 8x8 fuel 9x9 fuel	1.61544 cm 1.43002 cm
Reactor design thermal power	3833 MW
Core inlet temperature	278.9 °C
Core saturated temperature	287.7 °C
Core operating pressure	7.20 MPa operating
Reference Moderator Density	0.7367 g/cm^3
Radius of shroud outer diameter	268.29 cm
Shroud thickness	5.08 cm
Radius of liner of vessel wall	321.31 cm
Thickness of liner	0.476 cm
Vessel wall thickness	16.392 cm
Radius of insulation liner	351.79 cm
Thickness of insulation liner	0.159 cm

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Table 3. GG1 Reactor Core and Vessel Design Information (Continued)

Thickness of insulation	8.571 cm
General Description	**Dimension**
Radius of concrete wall	436.88 cm
Radius of jet pump and riser to core center	293 cm
Number of jet pumps	24
Location of jet pumps	every 15 degrees
Locations of risers	every 30 degrees
Jet pump inside diameter (ID)	18.212 cm
Jet pump outside diameter (OD)	20.752 cm
Riser ID	25.40 cm
Riser OD	28.245 cm
Reactor Vessel	
Inner diameter	642.62 cm (21 ft 1 inch)
Base metal material	SA-302 Grade B
Wall thickness	16.393 cm (minimum)
Clad material	Weld-deposited E-308 Stainless Steel electrode
Clad thickness	0.475 cm (minimum)
Reactor Internals Material	
Shroud	304 stainless steel
Core top grid and core bottom grid	Stainless steel
General Description	**Dimension**
Fuel support piece	304 stainless steel
Control blade guide tubes	Stainless steel
Incore instrument tubes	304 stainless steel
Core	
Equivalent core diameter	486.41 cm
Circumscribed core diameter	501.65 cm
Core lattice pitch	30.48 cm
Total fuel assemblies in core	800

Reference 3, p. 2-5

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Table 4. GG1 Reactor Core Information

Parameter	Dimension
Total number of assemblies	800
Number of fuel rods per assembly, 8x8 array / 9x9 array	62 / 76
Number of water rods, 8x8 array / 9x9 array	2 / 5
Channel (can)	13.246 cm wide, 0.3048 cm thick
Assembly pitch	15.24 cm
Pin pitch 8x8 array, 9x9 array	1.61544 cm, 1.43002 cm
Core inlet temperature	551.9 °K, (534.0 °F, 278.9 °C)
Core saturated temperature	560.7 °K, (549.9 °F, 287.7 °C)
Fuel clad temperature (Estimated)	588.6 °K (600.0 °F, 315.6 °C)
Core operating pressure	7.20 MPa operating (1044 psia)
Reference Moderator Density	0.7367 g/cm^3
Fuel Clad, Water Rod Clad, Channel Material	Zircaloy

Reference 3, p. 2-5

Table 5. GG1 Control Blade Technical Information

Parameter	Value
Neutron absorber material	B_4C (natural boron)
Percent of B_4C theoretical density	70
Total blade span tip to tip	24.902 cm
Total blade support span	3.937 cm
Active absorber length	364.998 cm (min) 365.76 cm (typical)
Sheath material	304 stainless steel
Sheath thickness	0.1143 cm
Blade thickness	0.8331 cm
Number of B_4C rods per blade	72
B_4C cladding material	304 stainless steel
B_4C rod OD	0.5588 cm
B_4C rod ID	0.4216 cm
B_4C rod wall thickness	0.06858 cm

Reference 3, p. 2-6

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Table 6. GG1 Technical Information for Fuel Types A, B, C, & D

		Cycle 2	Cycle 3	Cycle 4
Parameter	**Units**	**Fuel Type "A"**	**Fuel Types "B" & "C"**	**Fuel Type "D"**
Pellet Diameter	cm	1.02997 (Highest Enrichment) 1.02743 (Other Enrichments)	1.02997 (Highest Enrichment) 1.02743 (Other Enrichments)	1.02997 (Highest Enrichment) 1.02743 (Other Enrichments)
Stack Height Density (based on fuel pellet smeared to cladding ID) = (fuel pellet stack mass) / (volume within the clad along active fuel length)	g/cm^3	9.82 for highest enriched pellet in batch 9.77 for other enrichments without Gd 9.87 for natural pellets 9.66 for 3 wt % Gd pellets 9.63 for 4 wt % Gd pellets 9.60 for 5 wt % Gd pellets		
Pellet Density	% Theoretical Density	94.5	94.5	94.5
Fuel Cladding ID	cm	1.05156	1.05156	1.05156
Fuel Cladding OD	cm	1.22936	1.22936	1.22936
Active Fuel Length	cm	381.00	381.00	381.00
Plenum Length	cm	25.46096	25.46096	25.46096
Water Rod ID	cm	1.05156	1.05156	1.05156
Water Rod OD	cm	1.22936	1.22936	1.22936
Spacer Capture Rod ID	cm	1.05156	1.05156	1.05156
Spacer Capture Rod OD	cm	1.22936	1.22936	1.22936
Number of Fuel Rods per Bundle		62	62	62
Water Rods		1	1	1
SCRs		1	1	1

Reference 3, p2-7

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Table 7. GG1 Technical Information for Fuel Types E, F, G, H, J, K, L, M, & N

Parameter	Units	Cycle 4	Cycle 5	Cycle 6	Cycle 7	Cycle 8
		Fuel Type "E"	Fuel Type "F" & "G"	Fuel Types "H" & "J"	Fuel Types "K" & "L"	Fuel Types "M" & "N"
Pellet Diameter	cm	0.95123 (Large) 0.89535 (Small)		0.95123 (Large) 0.89662 (Small)		
Stack Height Density (based on fuel pellet smeared to cladding ID) = (fuel pellet stack mass) / (volume within the clad along active fuel length)	g/cm^3	Large Pellets: 9.82 (enriched) 9.89 (natural) 9.77 (3.0 wt % Gd) 9.725 (4.5 wt % Gd) 9.695 (5.5 wt % Gd) 9.65 (7.0 wt % Gd) Small Pellets: 9.80 (enriched) 9.87 (natural) 9.75 (3.0 wt % Gd) 9.705 (4.5 wt % Gd) 9.675 (5.5 wt % Gd) 9.63 (7.0 wt % Gd)		Large Pellets: 9.77 (enriched) 9.77 (natural) 9.73 (3.0 wt % Gd) 9.71 (3.5 wt % Gd) 9.68 (4.5 wt % Gd) 9.64 (5.5 wt % Gd) 9.63 (6.0 wt % Gd) 9.61 (6.5 wt % Gd) 9.59 (7.0 wt % Gd) Small Pellets: 9.77 (enriched) 9.77 (natural) 9.73 (3.0 wt % Gd) 9.72 (3.5 wt % Gd) 9.68 (4.5 wt % Gd) 9.65 (5.5 wt % Gd) 9.63 (6.0 wt % Gd) 9.61 (6.5 wt % Gd) 9.60 (7.0 wt % Gd)		
Pellet Density	% Theoretical Density	94.5		94.5		
Fuel Cladding ID	cm	0.96774 (Large) 0.91186 (Small)		0.97028 (Large) 0.9144 (Small)		
Fuel Cladding OD	cm	1.12522 (Large) 1.05918 (Small)		1.12522 (Large) 1.05918 (Small)		
Active Fuel Length	cm	381.00		381.00		
Plenum Length	cm	24.4348		24.4348		
Water Rod ID	cm	1.32588		1.32588		
Water Rod OD	cm	1.38684		1.38684		
Spacer Capture Rod ID	cm	0.91186		0.9144		
Spacer Capture Rod OD	cm	1.05918		1.05918		
Number of Fuel Rods per Bundle		48 (Large) 28 (Small)		48 (Large) 28 (Small)		
Water Rods		4		4		
SCRs		1		1		

Reference 3, p 2-8

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Table 8. Grand Gulf Unit 1 Fuel Assembly Rod Pitch and Channel Data

Reload		**Cycle 2**	**Cycle 3**	**Cycle 4**	**Cycle 4**	**Cycle 5**	**Cycle 6**	**Cycle 7**	**Cycle 8**
Fuel Type(s)		**A**	**B & C**	**D**	**E**	**F & G**	**H & J**	**K & L**	**M & N**
Parameter	**Units**								
Rod Pitch	cm	1.61544	1.61544	1.61544	1.43002	1.43002	1.43002	1.43002	1.43002
Channel Thickness	cm	0.3048	0.3048	0.3048	0.3048	0.3048	0.3048	0.3048	0.3048
Channel Inside Width	cm	13.2461	13.2461	13.2461	13.2461	13.2461	13.2461	13.2461	13.2461
Channel Corner Inside Radius	cm	0.9652	0.9652	0.9652	0.9652	0.9652	0.9652	0.9652	0.9652

Reference 3, p 2-9

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Table 9. GG1 Fuel Assembly and Channel Dimensions Summary

Parameter	**Assembly Type (8x8)** **A, B, C & D**	**Assembly Type (9x9)** **E, F, & G**	**Assembly Type (9x9)** **H, J, K, L, M, & N**
Number of Fuel Rods	62		
Number of Fuel Rods , LD		48	48
Number of Fuel Rods, SD		28	28
No. of Water Rods	1	4	4
No. of Spacer Capture Rods (SCR)	1	1	1
Smeared Fuel OD, cm	1.05156		
Smeared Fuel OD, LD (cm)		0.96774	0.97028
Smeared Fuel OD, SD (cm)		0.91186	0.9144
Fuel Clad OD (cm)	1.22936		
Fuel Clad OD, LD (cm)		1.12522	1.12522
Fuel Clad OD, SD (cm)		1.05918	1.05918
Fuel Pin Pitch (cm)	1.61544	1.43002	1.43002
Fuel Assembly Pitch (cm)	15.24	15.24	15.24
Active Fuel Length (cm)	381.00	381.00	381.00
Pellet Theoretical Density %	94.5	94.5	94.5
Water Rod Material	Zircaloy	Zircaloy	Zircaloy
Water Rod ID (cm)	1.05156	1.32588	1.32588
Water Rod OD (cm)	1.22936	1.38684	1.38684
SCR ID (cm)	1.05156	0.91186	0.9144
SCR OD (cm)	1.22936	1.05918	1.05918
Water Channel (Can) Material	Zircaloy	Zircaloy	Zircaloy
Channel Thickness (cm)	0.3048	0.3048	0.3048
Channel Inside Width (cm)	13.2461	13.2461	13.2461
Channel Outside Width (cm)	13.8557	13.8557	13.8557

LD = Large Diameter
SD = Small Diameter
Note: Smeared Fuel Rod OD equals the Clad ID
Reference 3, Section 2

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Table 10. GG1 Smeared Fuel Pellet Densities

Parameter	A, B, C & D	E, F, & G	H, J, K, L, M, & N
Natural Uranium Pellets, g/cm^3	9.87		
Highest Enriched Uranium Pellets, g/cm^3	9.82		
All Other Uranium Pellets, g/cm^3	9.77		
Uranium rod with 3.0 wt % Gd, g/cm^3	9.66		
Uranium rod with 4.0 wt % Gd, g/cm^3	9.63		
Uranium rod with 5.0 wt % Gd, g/cm^3	9.60		
Large Diameter Natural Pellets, g/cm^3		9.89	9.77
Large Diameter Enriched Pellet, g/cm^{3}s		9.82	9.77
Large Diameter Pellet with 3.0 wt% Gd, g/cm^3		9.77	9.73
Large Diameter Pellet with 3.5 wt% Gd, g/cm^3			9.71
Large Diameter Pellet with 4.5 wt% Gd, g/cm^3		9.725	9.68
Large Diameter Pellet with 5.0 wt% Gd, g/cm^3		9.710	
Large Diameter Pellet with 5.5 wt% Gd, g/cm^3		9.695	9.64
Large Diameter Pellet with 6.0 wt% Gd, g/cm^3		9.680	9.63
Large Diameter Pellet with 6.5 wt% Gd, g/cm^3			9.61
Large Diameter Pellet with 7.0 wt% Gd, g/cm^3		9.65	9.59
Small Diameter Natural Pellets, g/cm^3		9.87	9.77
Small Diameter Enriched Pellets, g/cm^3		9.80	9.77
Small Diameter Pellet with 3.0 wt% Gd, g/cm^3		9.75	9.73
Small Diameter Pellet with 3.5 wt% Gd, g/cm^3			9.72
Small Diameter Pellet with 4.5 wt% Gd, g/cm^3		9.705	9.68
Small Diameter Pellet with 5.0 wt% Gd, g/cm^3		9.69	
Small Diameter Pellet with 5.5 wt% Gd, g/cm^3		9.675	9.65
Small Diameter Pellet with 6.0 wt% Gd, g/cm^3		9.66	9.63
Small Diameter Pellet with 6.5 wt% Gd, g/cm^3			9.61
Small Diameter Pellet with 7.0 wt% Gd, g/cm^3		9.63	9.60

Reference 3, p 2-7, 2-8

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5.2 GG1 CYCLES 2 THROUGH 8 FUEL ASSEMBLY HISTORY

The GG1 reactor core contains 800 fuel assemblies. The 800 fuel assemblies will be reduced to 400 for the MCNP calculations by modeling only the lower half of the core. The fuel assembly isotopic information from Reference 2 is only supplied for assemblies in one-eighth core and was expanded symmetrically to fill the half core geometry. This reduced the number of fuel isotopic data sets needed for use in MCNP for the 400 fuel assemblies from 400 to 106.

Each of the fuel assemblies was given a unique alphanumeric designation, which was then used in tracking the assembly through its entire period of exposure. This includes both the cycle and location where each fuel assembly was irradiated. Tables 11 through 20 and Figures 5 through 11 from Reference 3 pages 3-9 through 3-25 describe where each unique assembly ID is located in the one-eighth core which can then be expanded to half core. Beginning with fresh fuel type "A" for Cycle 2, each subsequent type of assembly is assigned a unique letter designation ("B" and "C" for fresh fuel in Cycle 3, "D" and "E" for Cycle 4, "F" and "G" for Cycle 5, "H" and "J" for Cycle 6, "K" and "L" for Cycle 7, and "M" and "N" for Cycle 8). For each fuel type designation, a number is assigned in the ascending order of the fuel assembly number that was loaded in the one-eighth core.

Tables 21 to 26 from Reference 2 give the fuel and Gad rod information by node for each of the fuel types. Figures 31 to 36 show the standard or generic placement of Gadolinia bearing fuel rods within the different fuel assembly types.

In summary, Tables 11 through 26 and Figures 5 through 11 and Figures 31 through 36 provide the following information:

- The cycles in which the various fuel assemblies were irradiated,
- The locations of the various fuel assemblies by core map row and column in each cycle for 1/8th core (see Figure 5 for example),
- The assembly identification and fuel type by node and the number and location of the Gadolinia rods by node for each fuel type.

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Table 11. GG1 Assembly Location for "A" Assemblies Cycles 2 – 8 ✓

Fuel Type Designation	Initial Cycle Loaded	Cycle 2 Location (i,j)	Cycle 3 Location (i,j)	Cycle 4 Location (i,j)	Cycle 5 Location (i,j)	Cycle 6 Location (i,j)	Cycle 7 Location (i,j)	Cycle 8 Location (i,j)
A1	2	23, 29	20, 30	29, 18	-	-	-	-
A2	2	19, 29	30, 19	23, 20	-	-	-	-
A3	2	24, 28	30, 22	29, 20	-	-	-	-
A4	2	18, 28	25, 20	32, 17	-	-	-	-
A5	2	25, 27	30, 17	22, 17	-	-	-	-
A6	2	21, 27	18, 17	31, 20	-	-	-	-
A7	2	19, 27	28, 23	29, 22	-	-	-	-
A8	2	24, 26	29, 18	30, 23	-	-	-	-
A9	2	18, 26	21, 28	31, 18	-	-	-	-
A10	2	27, 25	30, 21	23, 22	-	-	-	-
A11	2	21, 25	18, 23	30, 24	-	-	-	-
A12	2	29, 23	30, 20	19, 18	-	-	-	-
A13	2	27, 23	19, 28	29, 25	-	-	-	-
A14	2	25, 23	27, 22	32, 18	-	-	-	-
A15	2	23, 23	23, 28	28, 27	-	-	-	-
A16	2	17, 23	22, 29	31, 17	-	-	-	-
A17	2	30, 22	24, 27	25, 20	-	-	-	-
A18	2	28, 22	20, 25	29, 26	-	-	-	-
A19	2	26, 22	22, 23	29, 27	-	-	-	-
A20	2	22, 22	28, 17	31, 23	-	-	-	-
A21	2	18, 22	25, 22	28, 28	-	-	-	-
A22	2	27, 21	27, 26	25, 18	-	-	-	-
A23	2	25, 21	22, 25	31, 22	-	-	-	-
A24	2	30, 20	18, 30	21, 20	-	-	-	-
A25	2	28, 20	24, 29	21, 18	-	-	-	-
A26	2	18, 20	27, 18	31, 19	-	-	-	-
A27	2	27, 19	27, 28	27, 27	-	-	-	-
A28	2	23, 19	29, 20	29, 24	-	-	-	-
A29	2	30, 18	28, 25	26, 25	-	-	-	-
A30	2	22, 18	23, 30	17, 17	-	-	-	-
A31	2	18, 18	27, 20	31, 21	-	-	-	-

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Table 12. GG1 Assembly Location for "B" Assemblies Cycles 2 - 8 ✓

Fuel Type Designation	Initial Cycle Loaded	Cycle 2 Location (i,j)	Cycle 3 Location (i,j)	Cycle 4 Location (i,j)	Cycle 5 Location (i,j)	Cycle 6 Location (i,j)	Cycle 7 Location (i,j)	Cycle 8 Location (i,j)
B1	3	-	21, 17	28, 21	17, 17	-	-	-
B2	3	-	27, 17	26, 17	-	-	-	-
B3	3	-	18, 18	25, 22	31, 21	-	-	-
B4	3	-	20, 18	23, 21	24, 30	-	-	-
B5	3	-	22, 18	22, 21	32, 17	-	-	-
B6	3	-	24, 18	20, 19	-	-	-	-
B7	3	-	26, 18	28, 17	20, 31	-	-	-
B8	3	-	19, 19	21, 28	28, 17	-	-	-
B9	3	-	21, 19	26, 21	26, 29	-	-	-
B10	3	-	23, 19	30, 21	24, 17	-	-	-
B11	3	-	18, 20	27, 26	25, 18	-	-	-
B12	3	-	20, 20	26, 23	31, 23	-	-	-
B13	3	-	24, 20	19, 26	31, 19	-	-	-
B14	3	-	26, 20	22, 25	31, 22	-	-	-
B15	3	-	17, 21	26, 27	24, 21	-	-	-
B16	3	-	19, 21	26, 19	17, 31	-	-	-
B17	3	-	23, 21	30, 19	21, 24	-	-	-
B18	3	-	25, 21	27, 18	31, 17	-	-	-
B19	3	-	27, 21	20, 17	27, 29	-	-	-
B20	3	-	18, 22	21, 26	29, 26	-	-	-
B21	3	-	22, 22	30, 22	18, 19	-	-	-
B22	3	-	19, 23	28, 25	18, 25	-	-	-
B23	3	-	21, 23	23, 26	29, 27	-	-	-
B24	3	-	18, 24	24, 17	-	-	-	-
B25	3	-	20, 24	30, 17	24, 23	-	-	-
B26	3	-	22, 24	17, 20	32, 18	-	-	-
B27	3	-	24, 24	26, 28	23, 20	-	-	-
B28	3	-	26, 24	23, 18	-	-	-	-
B29	3	-	28, 24	24, 19	27, 26	-	-	-
B30	3	-	19, 25	19, 30	26, 17	-	-	-
B31	3	-	21, 25	18, 27	30, 24	-	-	-
B32	3	-	27, 25	20, 30	22, 17	-	-	-
B33	3	-	20, 26	27, 22	21, 31	-	-	-
B34	3	-	24, 26	28, 26	19, 21	-	-	-
B35	3	-	19, 27	18, 17	18, 32	-	-	-
B36	3	-	21, 27	30, 18	17, 26	-	-	-
B37	3	-	25, 27	30, 20	19, 18	-	-	-

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Table 13. GG1 Assembly Location for "C" Assemblies Cycles 2 - 8

Fuel Type Designation	Initial Cycle Loaded	Cycle 2 Location (i,j)	Cycle 3 Location (i,j)	Cycle 4 Location (i,j)	Cycle 5 Location (i,j)	Cycle 6 Location (i,j)	Cycle 7 Location (i,j)	Cycle 8 Location (i,j)
C1	3	-	19, 17	28, 23	20, 29	-	-	-
C2	3	-	29, 17	27, 24	29, 20	-	-	-
C3	3	-	17, 19	25, 24	25, 29	-	-	-
C4	3	-	28, 20	17, 30	26, 23	-	-	-
C5	3	-	21, 21	27, 20	18, 31	-	-	-
C6	3	-	29, 21	24, 21	17, 28	-	-	-
C7	3	-	26, 22	19, 28	31, 18	-	-	-
C8	3	-	23, 23	21, 19	31, 20	-	-	-
C9	3	-	27, 23	23, 24	28, 27	-	-	-
C10	3	-	25, 25	23, 28	29, 22	-	-	-
C11	3	-	22, 26	28, 19	29, 25	-	-	-
C12	3	-	23, 27	24, 23	28, 28	-	-	-
C13	3	-	22, 28	22, 19	17, 32	-	-	-
C14	3	-	17, 29	23, 29	21, 19	-	-	-
C15	3	-	19, 29	29, 23	17, 22	-	-	-
C16	3	-	21, 29	21, 24	28, 19	-	-	-

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Table 14. GG1 Assembly Location for "D" and "E" Assemblies Cycles 2 - 8 ✓

Fuel Type Designation	Initial Cycle Loaded	Cycle 2 Location (i,j)	Cycle 3 Location (i,j)	Cycle 4 Location (i,j)	Cycle 5 Location (i,j)	Cycle 6 Location (i,j)	Cycle 7 Location (i,j)	Cycle 8 Location (i,j)
D1	4	-	-	19, 17	18, 29	27, 26	-	-
D2	4	-	-	21, 17	27, 20	29, 26	-	-
D3	4	-	-	23, 17	30, 23	18, 20	-	-
D4	4	-	-	25, 17	24, 25	-	-	-
D5	4	-	-	27, 17	19, 22	32, 17	-	-
D6	4	-	-	29, 17	22, 21	31, 17	-	-
D7	4	-	-	18, 18	25, 20	-	-	-
D8	4	-	-	20, 18	27, 18	18, 32	-	-
D9	4	-	-	22, 18	29, 24	22, 27	-	-
D10	4	-	-	24, 18	24, 29	26, 25	-	-
D11	4	-	-	26, 18	17, 18	17, 32	-	-
D12	4	-	-	28, 18	25, 22	32, 18	-	-
D13	4	-	-	19, 19	19, 26	-	-	-
D14	4	-	-	23, 19	25, 28	29, 17	-	-
D15	4	-	-	25, 19	22, 30	20, 27	-	-
D16	4	-	-	27, 19	26, 19	29, 27	-	-
D17	4	-	-	29, 19	24, 27	29, 18	-	-
D18	4	-	-	20, 20	30, 19	30,18	-	-
D19	4	-	-	22, 20	21, 28	30, 23	-	-
D20	4	-	-	24, 20	30, 21	27, 22	-	-
D21	4	-	-	26, 20	26, 28	18, 27	-	-
D22	4	-	-	28, 20	21, 23	29, 25	-	-
D23	4	-	-	21, 21	27, 22	21, 31	-	-
D24	4	-	-	25, 21	20, 30	25, 26	-	-
D25	4	-	-	27, 21	20, 25	-	-	-
D26	4	-	-	29, 21	17, 20	31, 18	-	-
D27	4	-	-	18, 22	28, 23	24, 27	-	-
D28	4	-	-	22, 22	21, 20	27, 29	-	-
D29	4	-	-	24, 22	27, 27	27, 18	-	-
D30	4	-	-	26, 22	28, 21	31, 21	-	-

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Table 15. GG1 Assembly Location for "D" and "E" Assemblies Cycles 2 - 8 (Cont.)

Fuel Type Designation	Initial Cycle Loaded	Cycle 2 Location (i,j)	Cycle 3 Location (i,j)	Cycle 4 Location (i,j)	Cycle 5 Location (i,j)	Cycle 6 Location (i,j)	Cycle 7 Location (i,j)	Cycle 8 Location (i,j)
D31	4	-	-	28, 22	21, 26	31, 20	-	-
D32	4	-	-	17, 23	23, 30	19, 19	-	-
D33	4	-	-	19, 23	28, 25	29, 22	-	-
D34	4	-	-	23, 23	29, 18	27, 24	-	-
D35	4	-	-	25, 23	30, 18	17, 29	-	-
D36	4	-	-	27, 23	23, 18	26, 26	-	-
D37	4	-	-	18, 24	30, 22	20, 18	-	-
D38	4	-	-	22, 24	28, 26	27, 20	-	-
D39	4	-	-	24, 24	18, 30	29, 20	-	-
D40	4	-	-	26, 24	19, 24	23, 31	-	-
D41	4	-	-	28, 24	18, 21	20, 29	-	-
D42	4	-	-	17, 25	25, 24	22, 31	-	-
D43	4	-	-	19, 25	30, 20	17, 17	-	-
D44	4	-	-	21, 25	21, 30	28, 28	-	-
D45	4	-	-	25, 25	24, 19	30, 24	-	-
D46	4	-	-	27, 25	27, 24	22, 29	-	-
D47	4	-	-	18, 26	30, 17	18, 31	-	-
D48	4	-	-	17, 27	26, 25	31, 19	-	-
D49	4	-	-	19, 27	22, 19	24, 30	-	-
D50	4	-	-	21, 27	18, 17	20, 31	-	-
D51	4	-	-	25, 27	20, 19	29, 24	-	-
D52	4	-	-	18, 28	23, 22	31, 22	-	-
D53	4	-	-	20, 28	18, 23	31, 23	-	-
D54	4	-	-	22, 28	23, 21	19, 31	-	-
D55	4	-	-	24, 28	21, 18	21, 30	-	-
D56	4	-	-	17, 29	26, 21	23, 30	-	-
D57	4	-	-	21, 29	20, 17	30, 21	-	-
E1	4	-	-	26, 26	19, 20	25, 25	-	-

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Table 16. GG1 Assembly Location for "F" Assemblies Cycles 2 - 8

Fuel Type Designation	Initial Cycle Loaded	Cycle 2 Location (i,j)	Cycle 3 Location (i,j)	Cycle 4 Location (i,j)	Cycle 5 Location (i,j)	Cycle 6 Location (i,j)	Cycle 7 Location (i,j)	Cycle 8 Location (i,j)
F1	5	-	-	-	23, 17	18, 19	-	-
F2	5	-	-	-	25, 17	21, 22	22, 31	-
F3	5	-	-	-	27, 17	18, 23	25, 29	-
F4	5	-	-	-	29, 17	30, 20	20, 25	-
F5	5	-	-	-	18, 18	23, 20	19, 31	-
F6	5	-	-	-	20, 18	19, 20	31, 23	-
F7	5	-	-	-	24, 18	18, 21	28, 26	-
F8	5	-	-	-	28, 18	28, 25	27, 18	-
F9	5	-	-	-	19, 19	23, 18	28, 27	-
F10	5	-	-	-	25, 19	19, 26	27, 28	-
F11	5	-	-	-	29, 19	28, 23	17, 17	-
F12	5	-	-	-	18, 20	20, 19	32, 18	-
F13	5	-	-	-	22, 20	24, 19	17, 31	-
F14	5	-	-	-	24, 20	23, 24	18, 32	-
F15	5	-	-	-	28, 20	22, 30	17, 20	-
F16	5	-	-	-	25, 21	19, 22	28, 28	-
F17	5	-	-	-	29, 21	30, 17	25, 20	-
F18	5	-	-	-	20, 22	19, 18	30, 24	-
F19	5	-	-	-	24, 22	19, 24	-	-
F20	5	-	-	-	28, 22	23, 26	27, 26	-
F21	5	-	-	-	17, 23	21, 18	-	-
F22	5	-	-	-	25, 23	18, 25	-	-
F23	5	-	-	-	27, 23	24, 25	29, 24	-
F24	5	-	-	-	29, 23	17, 28	20, 27	-
F25	5	-	-	-	18, 24	22, 17	17, 32	-
F26	5	-	-	-	20, 24	24, 23	-	-
F27	5	-	-	-	22, 24	26, 19	29, 25	-
F28	5	-	-	-	28, 24	19, 30	27, 22	-
F29	5	-	-	-	17, 25	25, 18	31, 21	-
F30	5	-	-	-	19, 25	22, 19	29, 27	-
F31	5	-	-	-	23, 25	22, 21	21, 31	-
F32	5	-	-	-	27, 25	27, 27	24, 24	-
F33	5	-	-	-	26, 26	28, 19	24, 27	-
F34	5	-	-	-	23, 27	25, 24	18, 30	-
F35	5	-	-	-	25, 27	19, 28	29, 18	-
F36	5	-	-	-	18, 28	30, 22	20, 17	-
F37	5	-	-	-	22, 28	26, 23	23, 29	-
F38	5	-	-	-	19, 29	23, 28	27, 24	-
F39	5	-	-	-	21, 29	30, 19	25, 22	-
F40	5	-	-	-	23, 29	28, 17	27, 20	-

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Table 17. GG1 Assembly Location for "G" Assemblies Cycles 2 - 8

Fuel Type Designation	Initial Cycle Loaded	Cycle 2 Location (I,J)	Cycle 3 Location (I,J)	Cycle 4 Location (I,J)	Cycle 5 Location (I,J)	Cycle 6 Location (I,J)	Cycle 7 Location (I,J)	Cycle 8 Location (I,J)
G1	5	-	-	-	19, 17	27, 28	19, 20	-
G2	5	-	-	-	21, 17	20, 25	29, 26	-
G3	5	-	-	-	22, 18	17, 20	31, 19	-
G4	5	-	-	-	26, 18	17, 26	24, 29	-
G5	5	-	-	-	17, 19	21, 26	31, 18	-
G6	5	-	-	-	23, 19	20, 17	26, 28	-
G7	5	-	-	-	27, 19	28, 21	18, 29	-
G8	5	-	-	-	20, 20	21, 20	31, 20	-
G9	5	-	-	-	26, 20	22, 25	24, 30	-
G10	5	-	-	-	17, 21	25, 20	30, 23	-
G11	5	-	-	-	21, 21	20, 21	18, 31	-
G12	5	-	-	-	27, 21	21, 28	29, 23	-
G13	5	-	-	-	22, 22	22, 23	23, 30	-
G14	5	-	-	-	26, 22	17, 18	-	-
G15	5	-	-	-	19, 23	24, 21	31, 22	-
G16	5	-	-	-	23, 23	26, 17	30, 18	-
G17	5	-	-	-	24, 24	18, 17	-	-
G18	5	-	-	-	26, 24	28, 26	18, 25	-
G19	5	-	-	-	25, 25	28, 27	20, 19	-
G20	5	-	-	-	18, 26	24, 17	31, 17	-
G21	5	-	-	-	20, 26	23, 22	27, 29	-
G22	5	-	-	-	22, 26	25, 22	23, 31	-
G23	5	-	-	-	24, 26	26, 28	25, 18	-
G24	5	-	-	-	19, 27	26, 21	26, 27	-
G25	5	-	-	-	21, 27	17, 24	32, 17	-

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Table 18. GG1 Assembly Location for "H" Assemblies Cycles 2 - 8

Fuel Type Designation	Initial Cycle Loaded	Cycle 2 Location (i,j)	Cycle 3 Location (i,j)	Cycle 4 Location (i,j)	Cycle 5 Location (i,j)	Cycle 6 Location (i,j)	Cycle 7 Location (i,j)	Cycle 8 Location (i,j)
H1	6	-	-	-	-	28, 18	26, 23	31, 19
H2	6	-	-	-	-	27, 19	21, 26	31, 17
H3	6	-	-	-	-	29, 19	27, 27	17, 17
H4	6	-	-	-	-	28, 20	28, 17	31, 18
H5	6	-	-	-	-	27, 21	26, 19	23, 30
H6	6	-	-	-	-	29, 21	25, 26	29, 18
H7	6	-	-	-	-	28, 22	28, 25	25, 18
H8	6	-	-	-	-	27, 23	30, 22	22, 25
H9	6	-	-	-	-	29, 23	19, 28	27, 24
H10	6	-	-	-	-	24, 24	24, 19	29, 24
H11	6	-	-	-	-	26, 24	23, 26	19, 31
H12	6	-	-	-	-	28, 24	21, 28	29, 20
H13	6	-	-	-	-	27, 25	23, 28	19, 18
H14	6	-	-	-	-	24, 26	23, 24	29, 25
H15	6	-	-	-	-	21, 27	26, 21	17, 31
H16	6	-	-	-	-	25, 27	28, 23	18, 19
H17	6	-	-	-	-	18, 28	19, 26	30, 23
H18	6	-	-	-	-	20, 28	24, 23	25, 29
H19	6	-	-	-	-	22, 28	22, 30	25, 22
H20	6	-	-	-	-	24, 28	28, 21	20, 29
H21	6	-	-	-	-	21, 29	26, 25	18, 29
H22	6	-	-	-	-	23, 29	28, 19	24, 27

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Table 19. GG1 Assembly Location for "J" Assemblies Cycles 2 - 8 ✓

Fuel Type Designation	Initial Cycle Loaded	Cycle 2 Location (i,j)	Cycle 3 Location (i,j)	Cycle 4 Location (i,j)	Cycle 5 Location (i,j)	Cycle 6 Location (i,j)	Cycle 7 Location (i,j)	Cycle 8 Location (i,j)
J1	6	-	-	-	-	19, 17	30, 21	20, 27
J2	6	-	-	-	-	21, 17	21, 22	28, 28
J3	6	-	-	-	-	23, 17	20, 21	31, 20
J4	6	-	-	-	-	25, 17	21, 18	29, 26
J5	6	-	-	-	-	27, 17	17, 18	-
J6	6	-	-	-	-	18, 18	30, 19	18, 27
J7	6	-	-	-	-	22, 18	22, 17	27, 29
J8	6	-	-	-	-	24, 18	18, 21	-
J9	6	-	-	-	-	26, 18	21, 24	28, 27
J10	6	-	-	-	-	17, 19	21, 30	27, 20
J11	6	-	-	-	-	21, 19	28, 24	22, 27
J12	6	-	-	-	-	23, 19	17, 22	29, 27
J13	6	-	-	-	-	25, 19	24, 21	-
J14	6	-	-	-	-	20, 20	23, 20	23, 31
J15	6	-	-	-	-	22, 20	19, 22	31, 21
J16	6	-	-	-	-	24, 20	24, 28	27, 22
J17	6	-	-	-	-	26, 20	21, 20	20, 31
J18	6	-	-	-	-	19, 21	22, 19	21, 31
J19	6	-	-	-	-	21, 21	18, 19	-
J20	6	-	-	-	-	23, 21	22, 21	-
J21	6	-	-	-	-	25, 21	25, 24	26, 28
J22	6	-	-	-	-	18, 22	24, 25	28, 26
J23	6	-	-	-	-	22, 22	26, 17	17, 32
J24	6	-	-	-	-	24, 22	30, 17	27, 28
J25	6	-	-	-	-	26, 22	26, 26	30, 24
J26	6	-	-	-	-	17, 23	30, 20	25, 20
J27	6	-	-	-	-	19, 23	17, 26	32, 17
J28	6	-	-	-	-	21, 23	24, 17	-
J29	6	-	-	-	-	23, 23	22, 29	24, 25
J30	6	-	-	-	-	25, 23	23, 18	32, 18
J31	6	-	-	-	-	20, 24	29, 20	31, 22
J32	6	-	-	-	-	17, 25	29, 22	25, 24
J33	6	-	-	-	-	19, 25	19, 30	27, 18
J34	6	-	-	-	-	21, 25	17, 30	21, 21
J35	6	-	-	-	-	23, 25	20, 23	31, 23
J36	6	-	-	-	-	18, 26	23, 22	-
J37	6	-	-	-	-	20, 26	19, 18	-
J38	6	-	-	-	-	17, 27	18, 17	-

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Table 20. GG1 Assembly Location for "K" "L" "M" and "N" Assemblies Cycles 2 - 8

K Assemblies			
Fuel Designation	Initial Cycle Loaded	Cycle 7 Location (i, j)	Cycle 8 Location (i, j)
K1	7	19, 17	30 ,21
K2	7	21, 17	24, 19
K3	7	18, 18	17, 30
K4	7	20, 18	26, 25
K5	7	26, 18	28, 24
K6	7	28, 18	25, 28
K7	7	19, 19	28, 17
K8	7	20, 20	30, 17
K9	7	24, 20	21, 28
K10	7	26, 20	21, 20
K11	7	28, 20	26, 21
K12	7	22, 22	17, 28
K13	7	24, 22	23, 28
K14	7	26, 22	19, 28
K15	7	20, 24	28, 21
K16	7	22, 24	28, 23
K17	7	26, 24	19, 30
K18	7	22, 26	28, 19
K19	7	24, 26	30, 19
K20	7	18, 28	28, 25

L Assemblies			
Fuel Designation	Initial Cycle Loaded	Cycle 7 Location (i, j)	Cycle 8 Location (i, j)
L1	7	23, 17	23, 20
L2	7	25, 17	19, 22
L3	7	27, 17	24, 17
L4	7	29, 17	17, 26
L5	7	22, 18	22, 29
L6	7	24, 18	19, 26
L7	7	21, 19	20, 17
L8	7	23, 19	19, 20
L9	7	25, 19	20, 23
L10	7	27, 19	24, 21
L11	7	29, 19	30, 20
L12	7	22, 20	23, 18
L13	7	21, 21	26, 27
L14	7	23, 21	23, 24
L15	7	25, 21	17, 22
L16	7	27, 21	18, 21
L17	7	29, 21	26, 23
L18	7	18, 22	29, 22
L19	7	28, 22	22, 30
L20	7	17, 23	22, 21
L21	7	19, 23	20, 19
L22	7	21, 23	24, 23
L23	7	23, 23	27, 26
L24	7	25, 23	22, 23
L25	7	27, 23	17, 18
L26	7	18, 24	26, 19
L27	7	17, 25	22, 19
L28	7	21, 25	22, 17
L29	7	23, 25	23, 22
L30	7	25, 25	27, 27
L31	7	27, 25	18, 30
L32	7	21, 27	21, 18
L33	7	23, 27	18, 17
L34	7	25, 27	30, 18
L35	7	22, 28	30, 22
L36	7	17, 29	26, 17

M and N Assemblies		
Fuel Designation	Initial Cycle Loaded	Cycle 8 Location (i, j)
M1	8	29, 17
M2	8	20, 18
M3	8	22, 18
M4	8	24, 18
M5	8	21, 19
M6	8	23, 19
M7	8	20, 20
M8	8	22, 20
M9	8	23, 21
M10	8	22, 22
M11	8	24, 22
M12	8	28, 22
M13	8	23, 23
M14	8	27, 25
M15	8	19, 17
M16	8	21, 17
M17	8	23, 17
M18	8	25, 17
M19	8	27, 17
N1	8	27, 19
N2	8	29, 19
N3	8	24, 20
N4	8	26, 20
N5	8	28, 20
N6	8	25, 21
N7	8	27, 21
N8	8	29, 21
N9	8	26, 22
N10	8	25, 23
N11	8	27, 23
N12	8	29, 23
N13	8	24, 24
N14	8	26, 24
N15	8	25, 25
N16	8	26, 26
N17	8	18, 18
N18	8	26, 18
N19	8	28, 18
N20	8	19, 19
N21	8	25, 19

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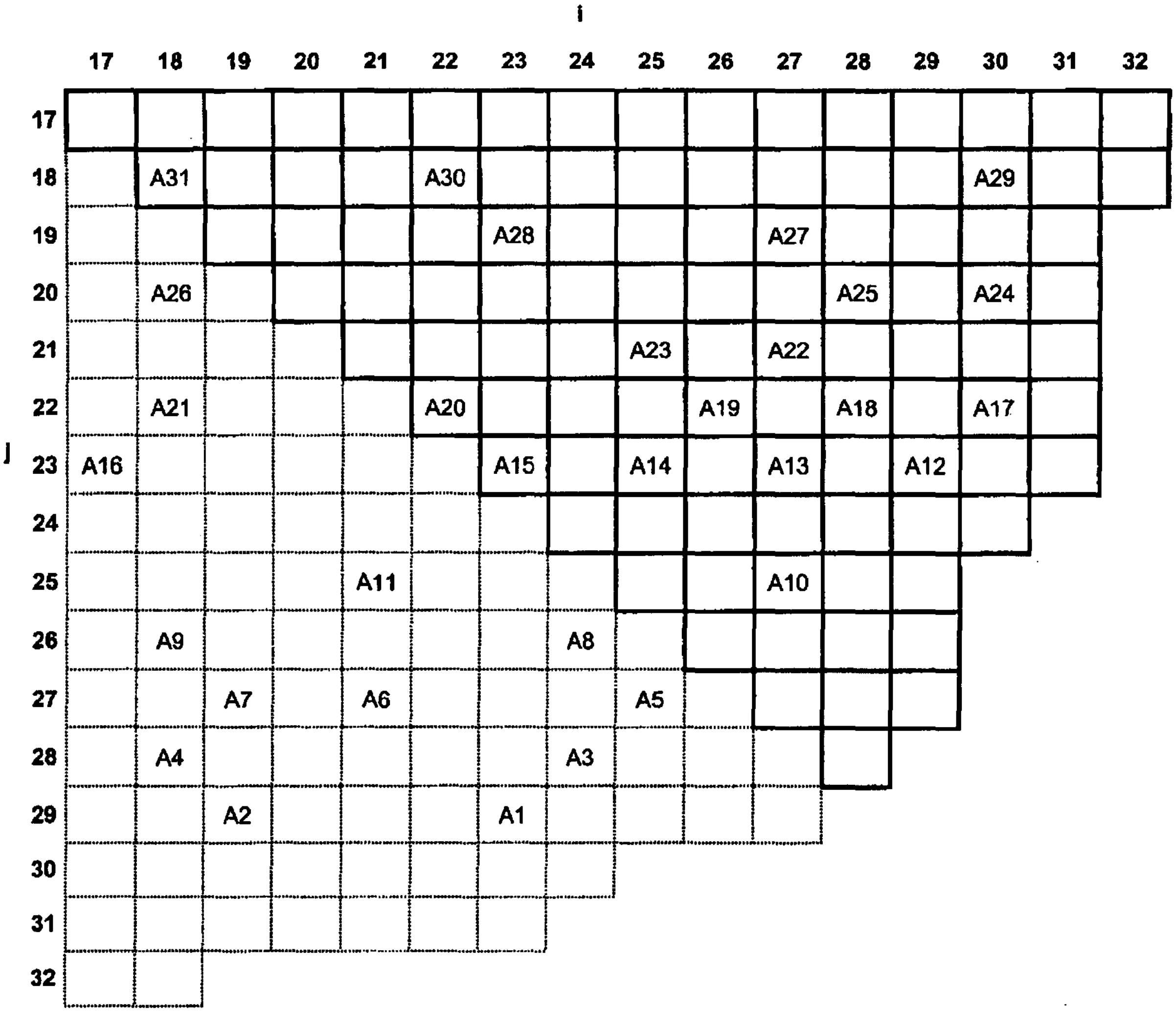
Figure 5. GG1 Cycle 2 Fuel Assembly Identification and Location



i

J	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
17																
18		A31				A30								A29		
19							A28				A27					
20		A26										A25		A24		
21									A23		A22					
22		A21				A20				A19		A18		A17		
23	A16						A15		A14		A13		A12			
24																
25					A11						A10					
26		A9						A8								
27			A7		A6				A5							
28		A4						A3								
29			A2				A1									
30																
31																
32																

FI	Fuel Assembly Designation (Ai are fresh fuel in Cycle 2)

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Figure 6. GG1 Cycle 3 Fuel Assembly Identification and Location

i

J	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
17		A6	C1		B1						B2	A20	C2	A5		
18		B3		B4		B5		B6		B7	A26		A8			
19	C3		B8		B9		B10							A2		
20		B11		B12				B13	A4	B14	A31	C4	A28	A12		
21	B15		B16		C5		B17		B18		B19		C6	A10		
22		B20				B21			A21	C7	A14			A3		
23		A11	B22		B23	A19	C8				C9	A7				
24		B24		B25		B26		B27		B28		B29				
25			B30	A18	B31	A23			C10		B32	A29				
26				B33		C11		B34			A22					
27			B35		B36		C12	A17	B37							
28			A13		A9	C13	A15				A27					
29	C14		C15		C16	A16		A25								
30		A24		A1			A30									
31																
32																

FI	Fuel Assembly Designation (BI and CI are fresh fuel in Cycle 3)

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Figure 7. GG1 Cycle 4 Fuel Assembly Identification and Location

I

J	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
17	A30	B35	D1	B19	D2	A5	D3	B24	D4	B2	D5	B7	D6	B25	A16	A4
18		D7	A12	D8	A25	D9	B28	D10	A22	D11	B18	D12	A1	B36	A9	A14
19			D13	B6	C8	C13	D14	B29	D15	B16	D16	C11	D17	B17	A26	
20	B26			D18	A24	D19	A2	D20	A17	D21	C5	D22	A3	B37	A6	
21					D23	B5	B4	C6	D24	B9	D25	B1	D26	B10	A31	
22		D27				D28	A10	D29	B3	D30	B33	D31	A7	B21	A23	
23	D32		D33				D34	C12	D35	B12	D36	C1	C15	A8	A20	
24		D37			C16	D38	C9	D39	C3	D40	C2	D41	A28	A11		
25	D42		D43		D44	B14			D45	A29	D46	B22	A13			
26		D47	B13		B20		B23			E1	B11	B34	A18			
27	D48	B31	D49		D50				D51	B15	A27	A15	A19			
28		D52	C7	D53	B8	D54	C10	D55		B27		A21				
29	D56				D57		C14									
30	C4		B30	B32												
31																
32																

Fi	Fuel Assembly Designation (Di and Ei are fresh fuel in Cycle 4)

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Figure 8. GG1 Cycle 5 Fuel Assembly Identification and Location

I

J	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
17	B1	D50	G1	D57	G2	B32	F1	B10	F2	B30	F3	B8	F4	D47	B18	B5
18	D11	F5	B37	F6	D55	G3	D36	F7	B11	G4	D8	F8	D34	D35	C7	B26
19	G5	B21	F9	D51	C14	D49	G6	D45	F10	D16	G7	C16	F11	D18	B13	
20	D26	F12	E1	G8	D28	F13	B27	F14	D7	G9	D2	F15	C2	D43	C8	
21	G10	D41	B34		G11	D6	D54	B15	F16	D56	G12	D30	F17	D20	B3	
22	C15		D5	F18		G13	D52	F19	D12	G14	D23	F20	C10	D37	B14	
23	F21	D53	G15		D22		G16	B25	F22	C4	F23	D27	F24	D3	B12	
24		F25	D40	F26	B17	F27		G17	D42	G18	D46	F28	D9	B31		
25	F29	B22	F30	D25			F31	D4	G19	D48	F32	D33	C11			
26	B36	G20	D13	G21	D31	G22		G23		F33	B29	D38	B20			
27			G24		G25		F34	D17	F35		D29	C9	B23			
28	C6	F36			D19	F37			D14	D21		C12				
29		D1	F38	C1	F39		F40	D10	C3	B9	B19					
30		D39		D24	D44	D15	D32	B4								
31	B16	C5		B7	B33											
32	C13	B35														

Fi	Fuel Assembly Designation (Fi and Gi are fresh fuel in Cycle 5)

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Figure 9. GG1 Cycle 6 Fuel Assembly Identification and Location

i

j	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
17	D43	G17	J1	G6	J2	F25	J3	G20	J4	G16	J5	F40	D14	F17	D6	D5
18	G14	J6	F18	D37	F21	J7	F9	J8	F29	J9	D29	H1	D17	D18	D26	D12
19	J10	F1	D32	F12	J11	F30	J12	F13	J13	F27	H2	F33	H3	F39	D48	
20	G3	D3	F6	J14	G8	J15	F5	J16	G10	J17	D38	H4	D39	F4	D31	
21		F7	J18	G11	J19	F31	J20	G15	J21	G24	H5	G7	H6	D57	D30	
22		J22	F16		F2	J23	G21	J24	G22	J25	D20	H7	D33	F36	D52	
23	J26	F3	J27		J28	G13	J29	F26	J30	F37	H8	F11	H9	D19	D53	
24	G25		F19	J31			F14	H10	F34	H11	D34	H12	D51	D45		
25	J32	F22	J33	G2	J34	G9	J35	F23	E1	D10	H13	F8	D22			
26	G4	J36	F10	J37	G5		F20	H14	D24	D36	D1	G18	D2			
27	J38	D21		D15	H15	D9		D27	H16		F32	G19	D16			
28	F24	H17	F35	H18	G12	H19	F38	H20		G23	G1	D44				
29	D35			D41	H21	D46	H22				D28					
30			F28		D55	F15	D56	D49								
31		D47	D54	D50	D23	D42	D40									
32	D11	D8														

Fi	Fuel Assembly Designation (Hi and Ji are fresh fuel in Cycle 6)

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Figure 10. GG1 Cycle 7 Fuel Assembly Identification and Location

i

j	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
17	F11	J38	K1	F36	K2	J7	L1	J28	L2	J23	L3	H4	L4	J24	G20	G25
18	J5	K3	J37	K4	J4	L5	J30	L6	G23	K5	F8	K6	F35	G16	G5	F12
19		J19	K7	G19	L7	J18	L8	H10	L9	H5	L10	H22	L11	J6	G3	
20	F15		G1	K8	J17	L12	J14	K9	F17	K10	F40	K11	J31	J26	G8	
21		J8		J3	L13	J20	L14	J13	L15	H15	L16	H20	L17	J1	F29	
22	J12	L18	J15		J2	K12	J36	K13	F39	K14	F28	L19	J32	H8	G15	
23	L20		L21	J35	L22		L23	H18	L24	H1	L25	H16	G12	G10	F6	
24		L26		K15	J9	K16	H14	F32	J21	K17	F38	J11	F23	F18		
25	L27	G18		F4	L28		L29	J22	L30	H21	L31	H7	F27			
26	J27		H17		H2	K18	H11	K19	H6	J25	F20	F7	G2			
27				F24	L32		L33	F33	L34	G24	H3	F9	F30			
28		K20	H9		H12	L35	H13	J16		G6	F10	F16				
29	L36	G7				J29	F37	G4	F3		G21					
30	J34	F34	J33		J10	H19	G13	G9								
31	F13	G11	F5		F31	F2	G22									
32	F25	F14														

Fi	Fuel Assembly Designation (Ki and Li are fresh fuel in Cycle 7)

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Figure 11. GG1 Cycle 8 Fuel Assembly Identification and Location

i

j	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
17	H3	L33	M15	L7	M16	L28	M17	L3	M18	L36	M19	K7	M1	K8	H2	J27
18	L25	N17	H13	M2	L32	M3	L12	M4	H7	N18	J33	N19	H6	L34	H4	J30
19		H16	N20	L21	M5	L27	M6	K2	N21	L26	N1	K18	N2	K19	H1	
20			L8	M7	K10	M8	L1	N3	J26	N4	J10	N5	H12	L11	J3	
21		L16			J34	L20	M9	L10	N6	K11	N7	K15	N8	K1	J15	
22	L15		L2			M10	L29	M11	H19	N9	J16	M12	L18	L35	J31	
23				L9		L24	M13	L22	N10	L17	N11	K16	N12	H17	J35	
24							L14	N13	J32	N14	H9	K5	H10	J25		
25						H8		J29	N15	K4	M14	K20	H14			
26	L4		L6							N16	L23	J22	J4			
27		J6		J1		J11		H22		L13	L30	J9	J12			
28	K12		K14		K9		K13		K6	J21	J24	J2				
29		H21		H20		L5			H18		J7					
30	K3	L31	K17			L19	H5									
31	H15		H11	J17	J18		J14									
32	J23															

FI	Fuel Assembly Designation (MI and NI are fresh fuel in Cycle 8)

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Table 21. GG1 Nodal Data for Assembly Types A, B, C, and D ✓

Assy. Type ID	# of U rods	U235 wt %	# of high Enriched pins	UO2 g/cc	# of Gd rods	Gd_2O_3 wt%	UO2(Gd) g/cc	Node Ht (cm)
Axxn01	57	0.71	0	9.87	5	0.0	9.87	15.24
Axxn02	57	2.99	20	9.788	5	3.0	9.66	60.96
Axxn03	57	2.99	20	9.788	5	3.0	9.66	45.72
Axxn04	57	2.99	20	9.788	5	3.0	9.66	45.72
Axxn05	57	2.99	20	9.788	5	3.0	9.66	45.72
Axxn06	57	2.99	20	9.788	5	3.0	9.66	45.72
Axxn07	57	2.99	20	9.788	5	3.0	9.66	45.72
Axxn08	57	2.99	20	9.788	5	3.0	9.66	30.48
Axxn09	57	2.99	20	9.788	5	3.0	9.66	30.48
Axxn10	57	0.71	0	9.87	5	0.0	9.87	15.24
Bxxn01	54	0.71	0	9.87	8	0.0	9.87	15.24
Bxxn02	54	3.21	20	9.789	8	4.0	9.63	60.96
Bxxn03	54	3.21	20	9.789	8	4.0	9.63	45.72
Bxxn04	54	3.21	20	9.789	8	4.0	9.63	45.72
Bxxn05	54	3.21	20	9.789	8	4.0	9.63	45.72
Bxxn06	54	3.21	20	9.789	8	4.0	9.63	45.72
Bxxn07	54	3.21	20	9.789	8	4.0	9.63	45.72
Bxxn08	54	3.21	20	9.789	8	4.0	9.63	30.48
Bxxn09	54	3.21	20	9.789	8	4.0	9.63	30.48
Bxxn10	54	0.71	0	9.87	8	0.0	9.87	15.24
Cxxn01	56	0.71	0	9.87	6	0.0	9.87	15.24
Cxxn02	56	3.21	20	9.788	6	4.0	9.63	60.96
Cxxn03	56	3.21	20	9.788	6	4.0	9.63	45.72
Cxxn04	56	3.21	20	9.788	6	4.0	9.63	45.72
Cxxn05	56	3.21	20	9.788	6	4.0	9.63	45.72
Cxxn06	56	3.21	20	9.788	6	4.0	9.63	45.72
Cxxn07	56	3.21	20	9.788	6	4.0	9.63	45.72
Cxxn08	56	3.21	20	9.788	6	4.0	9.63	30.48
Cxxn09	56	3.21	20	9.788	6	4.0	9.63	30.48
Cxxn10	56	0.71	0	9.87	6	0.0	9.87	15.24
Dxxn01	54	0.71	0	9.87	8	0.0	9.87	15.24
Dxxn02	54	3.61	20	9.789	8	5.0	9.60	60.96
Dxxn03	54	3.61	20	9.789	8	5.0	9.60	45.72
Dxxn04	54	3.61	20	9.789	8	5.0	9.60	45.72
Dxxn05	54	3.61	20	9.789	8	5.0	9.60	45.72
Dxxn06	54	3.61	20	9.789	8	5.0	9.60	45.72
Dxxn07	54	3.61	20	9.789	8	5.0	9.60	45.72
Dxxn08	54	3.61	20	9.789	8	4.0	9.63	30.48
Dxxn09	54	3.61	20	9.789	8	4.0	9.63	30.48
Dxxn10	54	0.71	0	9.87	8	0.0	9.87	15.24

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Table 22. GG1 Nodal Data for Assembly Types E, F, G, and H, Large Diameter ✓

Assy. Type ID	# of LD U rods	U235 wt %	UO2 g/cc	# of LD Gd rods	Gd_2O_3 wt %	Gd rods g/cc	Node Ht (cm)
Exxn01	44	0.71	9.89	4	0.0	9.89	15.24
Exxn02	44	3.47	9.82	4	6.0	9.68	60.96
Exxn03	44	3.47	9.82	4	6.0	9.68	45.72
Exxn04	44	3.47	9.82	4	6.0	9.68	45.72
Exxn05	44	3.47	9.82	4	6.0	9.68	45.72
Exxn06	44	3.47	9.82	4	6.0	9.68	45.72
Exxn07	44	3.47	9.82	4	6.0	9.68	45.72
Exxn08	44	3.47	9.82	4	5.0	9.71	30.48
Exxn09	44	3.47	9.82	4	5.0	9.71	30.48
Exxn10	44	0.71	9.89	4	0.0	9.89	15.24
Fxxn01	44	0.71	9.89	4	0.0	9.89	15.24
Fxxn02	44	3.80	9.82	4	7.0	9.65	45.72
Fxxn03	44	3.80	9.82	4	7.0	9.65	30.48
Fxxn04	44	3.80	9.82	4	5.5	9.695	45.72
Fxxn05	44	3.80	9.82	4	5.5	9.695	45.72
Fxxn06	44	3.80	9.82	4	5.5	9.695	60.96
Fxxn07	44	3.80	9.82	4	5.5	9.695	60.96
Fxxn08	44	3.80	9.82	4	4.5	9.725	30.48
Fxxn09	44	3.80	9.82	4	3.0	9.77	15.24
Fxxn10	44	0.71	9.89	4	0.0	9.89	30.48
Gxxn01	44	0.71	9.89	4	0.0	9.89	15.24
Gxxn02	44	3.80	9.82	4	7.0	9.65	45.72
Gxxn03	44	3.80	9.82	4	7.0	9.65	30.48
Gxxn04	44	3.80	9.82	4	7.0	9.65	45.72
Gxxn05	44	3.80	9.82	4	7.0	9.65	45.72
Gxxn06	44	3.80	9.82	4	7.0	9.65	60.96
Gxxn07	44	3.80	9.82	4	7.0	9.65	60.96
Gxxn08	44	3.80	9.82	4	5.5	9.695	30.48
Gxxn09	44	3.80	9.82	4	4.5	9.725	15.24
Gxxn10	44	0.71	9.89	4	0.0	9.89	30.48
Hxxn01	44	0.71	9.77	4	0.0	9.77	15.24
Hxxn02	44	3.78	9.77	4	7.0	9.59	60.96
Hxxn03	44	3.78	9.77	4	7.0	9.59	45.72
Hxxn04	44	3.78	9.77	4	5.5	9.64	60.96
Hxxn05	44	3.78	9.77	4	5.5	9.64	45.72
Hxxn06	44	3.70	9.77	4	7.0	9.59	30.48
Hxxn07	44	3.70	9.77	4	7.0	9.59	30.48
Hxxn08	44	3.70	9.77	4	4.5	9.68	30.48
Hxxn09	44	3.70	9.77	4	3.0	9.73	30.48
Hxxn10	44	0.71	9.77	4	0.0	9.77	30.48

Reference 2, Table 16

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Table 23. GG1 Nodal Data for Assembly Types E, F, G, and H, Small Diameter ✓

Assy. Type ID	# of SD U rods	U235 wt %	UO2 g/cc	# of SD Gd rods	Gd_2O_3 wt %	Gd rods g/cc	Node Ht (cm)
Exxn01	24	0.71	9.87	4	0.0	9.87	15.24
Exxn02	24	3.47	9.80	4	6.0	9.66	60.96
Exxn03	24	3.47	9.80	4	6.0	9.66	45.72
Exxn04	24	3.47	9.80	4	6.0	9.66	45.72
Exxn05	24	3.47	9.80	4	6.0	9.66	45.72
Exxn06	24	3.47	9.80	4	6.0	9.66	45.72
Exxn07	24	3.47	9.80	4	6.0	9.66	45.72
Exxn08	24	3.47	9.80	4	5.0	9.69	30.48
Exxn09	24	3.47	9.80	4	5.0	9.69	30.48
Exxn10	24	0.71	9.87	4	0.0	9.87	15.24
Fxxn01	24	0.71	9.87	4	0.0	9.87	15.24
Fxxn02	24	3.80	9.80	4	7.0	9.63	45.72
Fxxn03	24	3.80	9.80	4	7.0	9.63	30.48
Fxxn04	24	3.80	9.80	4	5.5	9.675	45.72
Fxxn05	24	3.80	9.80	4	5.5	9.675	45.72
Fxxn06	24	3.80	9.80	4	5.5	9.675	60.96
Fxxn07	23	3.80	9.80	5	5.5	9.675	60.96
Fxxn08	23	3.80	9.80	5	4.5	9.705	30.48
Fxxn09	23	3.80	9.80	5	3.0	9.75	15.24
Fxxn10	24	0.71	9.87	4	0.0	9.87	30.48
Gxxn01	22	0.71	9.87	6	0.0	9.87	15.24
Gxxn02	22	3.80	9.80	6	7.0	9.63	45.72
Gxxn03	22	3.80	9.80	6	7.0	9.63	30.48
Gxxn04	23	3.80	9.80	5	7.0	9.63	45.72
Gxxn05	23	3.80	9.80	5	7.0	9.63	45.72
Gxxn06	23	3.80	9.80	5	7.0	9.63	60.96
Gxxn07	22	3.80	9.80	6	7.0	9.63	60.96
Gxxn08	22	3.80	9.80	6	5.5	9.675	30.48
Gxxn09	22	3.80	9.80	6	4.5	9.705	15.24
Gxxn10	22	0.71	9.87	6	0.0	9.87	30.48
Hxxn01	23	0.71	9.77	5	0.0	9.77	15.24
Hxxn02	24	3.78	9.77	4	7.0	9.60	60.96
Hxxn03	24	3.78	9.77	4	7.0	9.60	45.72
Hxxn04	24	3.78	9.77	4	5.5	9.65	60.96
Hxxn05	24	3.78	9.77	4	5.5	9.65	45.72
Hxxn06	23	3.70	9.77	5	7.0	9.60	30.48
Hxxn07	23	3.70	9.77	5	7.0	9.60	30.48
Hxxn08	23	3.70	9.77	5	4.5	9.68	30.48
Hxxn09	23	3.70	9.77	5	3.0	9.73	30.48
Hxxn10	23	0.71	9.77	5	0.0	9.77	30.48

Reference 2, Table 17

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Table 24. GG1 Nodal Data for Assembly Types J, K, L, and M, Large Diameter ✓

Assembly Type ID	# of LD U rods	U235 wt %	UO2 g/cc	# of LD Gd rods	Gd_2O_3 wt %	Gd rods g/cc	Node Ht (cm)
Jxxn01	44	0.71	9.77	4	0.0	9.77	15.24
Jxxn02	44	3.28	9.77	4	7.0	9.59	60.96
Jxxn03	44	3.28	9.77	4	7.0	9.59	45.72
Jxxn04	44	3.28	9.77	4	5.5	9.64	60.96
Jxxn05	44	3.28	9.77	4	5.5	9.64	45.72
Jxxn06	44	3.19	9.77	4	7.0	9.59	30.48
Jxxn07	44	3.19	9.77	4	7.0	9.59	30.48
Jxxn08	44	3.19	9.77	4	7.0	9.59	30.48
Jxxn09	44	3.19	9.77	4	4.5	9.68	30.48
Jxxn10	44	0.71	9.77	4	0.0	9.77	30.48
Kxxn01	44	0.71	9.77	4	0.0	9.77	15.24
Kxxn02	44	3.77	9.77	4	7.0	9.59	45.72
Kxxn03	44	3.77	9.77	4	7.0	9.59	30.48
Kxxn04	44	3.77	9.77	4	7.0	9.59	30.48
Kxxn05	44	3.87	9.77	4	6.0	9.63	45.72
Kxxn06	44	3.87	9.77	4	6.0	9.63	60.96
Kxxn07	44	3.77	9.77	4	7.0	9.59	30.48
Kxxn08	44	3.77	9.77	4	7.0	9.59	45.72
Kxxn09	44	3.77	9.77	4	3.5	9.71	45.72
Kxxn10	44	0.71	9.77	4	0.0	9.77	30.48
Lxxn01	44	0.71	9.77	4	0.0	9.77	15.24
Lxxn02	44	3.52	9.77	4	7.0	9.59	60.96
Lxxn03	44	3.52	9.77	4	7.0	9.59	45.72
Lxxn04	44	3.62	9.77	4	6.0	9.63	60.96
Lxxn05	44	3.62	9.77	4	6.0	9.63	45.72
Lxxn06	44	3.52	9.77	4	7.0	9.59	30.48
Lxxn07	44	3.52	9.77	4	7.0	9.59	30.48
Lxxn08	44	3.52	9.77	4	7.0	9.59	30.48
Lxxn09	44	3.52	9.77	4	3.5	9.71	30.48
Lxxn10	44	0.71	9.77	4	0.0	9.77	30.48
Mxxn01	44	0.71	9.77	4	0.0	9.77	15.24
Mxxn02	44	3.44	9.77	4	6.5	9.61	60.96
Mxxn03	44	3.44	9.77	4	6.5	9.61	45.72
Mxxn04	44	3.44	9.77	4	6.5	9.61	60.96
Mxxn05	44	3.44	9.77	4	6.5	9.61	45.72
Mxxn06	44	3.30	9.77	4	7.0	9.59	30.48
Mxxn07	44	3.30	9.77	4	7.0	9.59	30.48
Mxxn08	44	3.30	9.77	4	7.0	9.59	30.48
Mxxn09	44	3.30	9.77	4	3.5	9.71	30.48
Mxxn10	44	0.71	9.77	4	0.0	9.77	30.48

Reference 2, Table 18

09/24/03

Table 25. GG1 Nodal Data for Assembly Types J, K, L, and M, Small Diameter

Assembly Type ID	# of SD U rods	U235 wt %	UO2 g/cc	# of SD Gd rods	Gd_2O_3 wt %	Gd rods g/cc	Node Ht (cm)
Jxxn01	23	0.71	9.77	5	0.0	9.77	15.24
Jxxn02	23	3.28	9.77	5	7.0	9.60	60.96
Jxxn03	23	3.28	9.77	5	7.0	9.60	45.72
Jxxn04	24	3.28	9.77	4	5.5	9.65	60.96
Jxxn05	24	3.28	9.77	4	5.5	9.65	45.72
Jxxn06	23	3.19	9.77	5	7.0	9.60	30.48
Jxxn07	23	3.19	9.77	5	7.0	9.60	30.48
Jxxn08	23	3.19	9.77	5	7.0	9.60	30.48
Jxxn09	23	3.19	9.77	5	4.5	9.68	30.48
Jxxn10	23	0.71	9.77	5	0.0	9.77	30.48
Kxxn01	23	0.71	9.77	5	0.0	9.77	15.24
Kxxn02	23	3.77	9.77	5	7.0	9.60	45.72
Kxxn03	23	3.77	9.77	5	7.0	9.60	30.48
Kxxn04	23	3.77	9.77	5	7.0	9.60	30.48
Kxxn05	23	3.87	9.77	5	6.0	9.63	45.72
Kxxn06	23	3.87	9.77	5	6.0	9.63	60.96
Kxxn07	23	3.77	9.77	5	7.0	9.60	30.48
Kxxn08	23	3.77	9.77	5	7.0	9.60	45.72
Kxxn09	23	3.77	9.77	5	3.5	9.72	45.72
Kxxn10	23	0.71	9.77	5	0.0	9.77	30.48
Lxxn01	23	0.71	9.77	5	0.0	9.77	15.24
Lxxn02	24	3.52	9.77	4	7.0	9.60	60.96
Lxxn03	24	3.52	9.77	4	7.0	9.60	45.72
Lxxn04	24	3.62	9.77	4	6.0	9.63	60.96
Lxxn05	24	3.62	9.77	4	6.0	9.63	45.72
Lxxn06	23	3.52	9.77	5	7.0	9.60	30.48
Lxxn07	23	3.52	9.77	5	7.0	9.60	30.48
Lxxn08	23	3.52	9.77	5	7.0	9.60	30.48
Lxxn09	23	3.52	9.77	5	3.5	9.72	30.48
Lxxn10	23	0.71	9.77	5	0.0	9.77	30.48
Mxxn01	23	0.71	9.77	5	0.0	9.77	15.24
Mxxn02	24	3.44	9.77	4	6.5	9.61	60.96
Mxxn03	24	3.44	9.77	4	6.5	9.61	45.72
Mxxn04	24	3.44	9.77	4	6.5	9.61	60.96
Mxxn05	24	3.44	9.77	4	6.5	9.61	45.72
Mxxn06	23	3.30	9.77	5	7.0	9.60	30.48
Mxxn07	23	3.30	9.77	5	7.0	9.60	30.48
Mxxn08	23	3.30	9.77	5	7.0	9.60	30.48
Mxxn09	23	3.30	9.77	5	3.5	9.72	30.48
Mxxn10	23	0.71	9.77	5	0.0	9.77	30.48

Reference 2, Table 19

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Table 26. GG1 Nodal Data for Assembly Type N, Large Diameter ✓

Assembly Type ID	# of LD U rods	U235 wt %	UO2 g/cc	# of LD Gd rods	Gd_2O_3 wt %	Gd rods g/cc	Node Ht (cm)
Nxxn01	44	0.71	9.77	4	0.0	9.77	15.24
Nxxn02	44	4.06	9.77	4	6.5	9.61	45.72
Nxxn03	44	4.06	9.77	4	6.5	9.61	30.48
Nxxn04	44	4.06	9.77	4	6.5	9.61	30.48
Nxxn05	44	4.06	9.77	4	6.5	9.61	45.72
Nxxn06	44	4.06	9.77	4	6.5	9.61	60.96
Nxxn07	44	3.76	9.77	4	7.0	9.59	30.48
Nxxn08	44	3.76	9.77	4	7.0	9.59	45.72
Nxxn09	44	3.76	9.77	4	3.5	9.71	45.72
Nxxn10	44	0.71	9.77	4	0.0	9.77	30.48

Reference 2, Table 20

Table 27. GG1 Nodal Data for Assembly Type N, Small Diameter

Assembly Type ID	# of SD U rods	U235 wt %	UO2 g/cc	# of SD Gd rods	Gd_2O_3 wt %	Gd rods g/cc	Node Ht (cm)
Nxxn01	23	0.71	9.77	5	0.0	9.77	15.24
Nxxn02	24	4.06	9.77	4	6.5	9.61	45.72
Nxxn03	24	4.06	9.77	4	6.5	9.61	30.48
Nxxn04	24	4.06	9.77	4	6.5	9.61	30.48
Nxxn05	24	4.06	9.77	4	6.5	9.61	45.72
Nxxn06	24	4.06	9.77	4	6.5	9.61	60.96
Nxxn07	23	3.76	9.77	5	7.0	9.60	30.48
Nxxn08	23	3.76	9.77	5	7.0	9.60	45.72
Nxxn09	23	3.76	9.77	5	3.5	9.72	45.72
Nxxn10	23	0.71	9.77	5	0.0	9.77	30.48

Reference 2, Table 21

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5.3 CONROL BLADE INSERTION DATA FOR STATEPOINTS

Figures 12 through 19 give the control blade positions for each of the 16 different statepoints and were taken from Reference 3 pages 4-539 through 4-546. Figure 1 (Reference 3 page 4-423) shows the control blade position relative to the fuel assemblies in the lower right quarter of the core. Other quadrants are symmetrical to Figure 1 (Reference 3 page 4-422). BWR control blades enter from the bottom of the core. Fully inserted control blades are shown as 0 notches withdrawn. Blades with 48 notches withdrawn are fully removed from the core. Any control blade with notches withdrawn anywhere between 0 and 48 are partially inserted control blades. A notch is equal to 3 inches of blade movement. Blades are normally moved in multiples of 2 notches or 6 inches increment. Review of the control blade positions in Figures 12 to 19 show that partially withdrawn rods are always an even number of notches withdrawn confirming the two notch minimum movement. Note that for statepoint 15 an error was found in the positions for three of the blades as given in Reference 3 when checked against the original information received from Grand Gulf. The correct positions have been marked on Figure 16. The corrected positions were used in the MCNP calculations and were not needed in the Reference 2 fuel depletions. Reference 2 fuel depletions used full power rod insertions that were given in Reference 3.

TNA
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Critical Configuration, Statepoint 5, Cycle 4

Exposure 0 MWd/MTU Cy 4, Moderator Temperature 148.5 °F, Period 128 sec.

0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
2					0	0	0	0	0	0	0					
4			0	0	48	0	48	0	48	0	48	0	0			
6		0	0	0	0	0	0	0	0	0	0	0	0	0		
8		0	48	0	0	0	48	0	48	0	0	0	48	0		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	48	0	0	0	48	0	18	0	0	0	48	0	0	0	48	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	48	0	48	0	0	0	48	0	48	0	18	0	48	0	48	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	48	0	0	0	48	0	18	0	0	0	48	0	0	0	48	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
24		0	48	0	0	0	48	0	48	0	0	0	48	0		
26		0	0	0	0	0	0	0	0	0	0	0	0	0		
28			0	0	48	0	48	0	48	0	48	0	0			
30					0	0	0	0	0	0	0					
32																

Critical Configuration, Statepoint 6, Cycle 4

Exposure 109 MWd/MTU Cy 4, Moderator Temperature 188 °F, Period 90 sec.

0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
2					0	0	0	0	0	0	0					
4			0	0	48	0	48	0	48	0	48	0	0			
6		0	0	0	0	0	0	0	0	0	0	0	0	0		
8		0	48	0	0	0	48	0	48	0	0	0	48	0		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	48	0	0	0	48	0	48	0	12	0	48	0	0	0	48	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	48	0	48	0	0	0	48	0	48	0	48	0	48	0	48	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	48	0	0	0	48	0	48	0	0	0	48	0	0	0	48	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
24		0	48	0	0	0	48	0	48	0	0	0	48	0		
26		0	0	0	0	0	0	0	0	0	0	0	0	0		
28			0	0	48	0	48	0	48	0	48	0	0			
30					0	0	0	0	0	0	0					
32																

Figure 12. GG1 Control Blade Configuration in Notches Withdrawn (SP5 and SP6)

TWA
9/26/03

Critical Configuration, Statepoint 7, Cycle 4

Exposure 1998 MWd/MTU Cy 4, Moderator Temperature 221 °F, Period 110 sec.

0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
2					0	0	0	0	0	0	0					
4			0	48	0	48	0	48	0	48	0	48	0			
6		0	0	0	0	0	4	0	0	0	0	0	0	0		
8		48	0	48	0	48	0	48	0	48	0	48	0	48		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	
12	0	48	0	48	0	48	0	48	0	48	0	48	0	48	0	
14	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	
16	0	48	0	48	0	48	0	48	0	48	0	48	0	48	0	
18	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	
20	0	48	0	48	0	48	0	48	0	48	0	48	0	48	0	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	
24		48	0	48	0	48	0	48	0	48	0	48	0	48		
26		0	0	0	0	0	0	0	4	0	0	0	0	0		
28			0	48	0	48	0	48	0	48	0	48	0			
30					0	0	0	0	0	0	0					
32																

Critical Configuration, Statepoint 10, Cycle 5

Exposure 0 MWd/MTU Cy 5, Moderator Temperature 111 °F, Period 87 sec.

0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
2					0	0	0	0	0	0	0					
4			48	0	48	0	20	0	48	0	48	0	48			
6		0	0	0	0	0	0	0	0	0	0	0	0	0		
8		0	48	0	0	0	48	0	48	0	0	0	48	0		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	48	0	0	0	48	0	0	0	0	0	48	0	0	0	48	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	48	0	48	0	0	0	48	0	48	0	0	0	48	0	20	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	48	0	0	0	48	0	0	0	0	0	48	0	0	0	48	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
24		0	48	0	0	0	48	0	48	0	0	0	48	0		
26		0	0	0	0	0	0	0	0	0	0	0	0	0		
28			48	0	48	0	20	0	48	0	48	0	48			
30					0	0	0	0	0	0	0					
32																

Figure 13. GG1 Control Blade Configuration in Notches Withdrawn (SP7 and SP10)

TWA
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Critical Configuration, Statepoint 11, Cycle 5
Exposure 451 MWd/MTU Cy 5, Moderator Temperature 180 °F, Period 83 sec.

0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
2					0	0	0	0	0	0	0					
4			0	0	48	0	48	0	48	0	48	0	0			
6		0	0	0	0	0	0	0	0	0	0	0	0	0		
8		0	48	0	0	0	48	0	48	0	0	0	48	0		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	48	0	0	0	48	0	26	0	0	0	48	0	0	0	48	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	48	0	48	0	0	0	48	0	48	0	26	0	48	0	48	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	48	0	0	0	48	0	28	0	0	0	48	0	0	0	48	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
24		0	48	0	0	0	48	0	48	0	0	0	48	0		
26		0	0	0	0	0	0	0	0	0	0	0	0	0		
28			0	0	48	0	48	0	48	0	48	0	0			
30					0	0	0	0	0	0	0					
32																

Critical Configuration, Statepoint 12, Cycle 5
Exposure 4042 MWd/MTU Cy 5, Moderator Temperature 225.5 °F, Period 89 sec.

0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
2					0	0	0	0	0	0	0					
4			0	0	48	0	48	0	48	0	48	0	0			
6		0	0	0	0	0	0	0	0	0	0	0	0	0		
8		0	48	0	0	0	48	0	48	0	0	0	48	0		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	48	0	0	0	48	0	48	0	14	0	48	0	0	0	48	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	48	0	48	0	14	0	48	0	48	0	48	0	48	0	48	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	48	0	0	0	48	0	48	0	16	0	48	0	0	0	48	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
24		0	48	0	0	0	48	0	48	0	0	0	48	0		
26		0	0	0	0	0	0	0	0	0	0	0	0	0		
28			0	0	48	0	48	0	48	0	48	0	0			
30					0	0	0	0	0	0	0					
32																

Figure 14. GG1 Control Blade Configuration in Notches Withdrawn (SP11 and SP12)

TWA
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Critical Configuration, Statepoint 13, Cycle 5

Exposure 4506 MWd/MTU Cy 5, Moderator Temperature 209 °F, Period 163 sec.

0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
2					0	0	0	0	0	0	0					
4			0	0	0	48	0	48	0	48	0	0	0			
6		0	0	0	0	0	0	0	0	0	0	0	0	0		
8		0	0	48	0	48	0	48	0	0	0	48	0	0		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	0	48	0	48	0	48	0	48	0	48	0	48	0	48	0	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	0	48	0	48	0	48	0	48	0	48	0	48	0	48	0	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	0	48	0	48	0	48	0	48	0	48	0	48	0	48	0	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
24		0	0	48	0	8	0	48	0	48	0	48	0	0		
26		0	0	0	0	0	0	0	0	0	0	0	0	0		
28			0	0	0	48	0	48	0	48	0	0	0			
30					0	0	0	0	0	0	0					
32																

Critical Configuration, Statepoint 14, Cycle 5

Exposure 5550 MWd/MTU Cy 5, Moderator Temperature 174 °F, Period 140 sec.

0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
2					0	0	0	0	0	0	0					
4			0	0	0	48	0	48	0	48	0	0	0			
6		0	0	0	0	0	0	0	0	0	0	0	0	0		
8		0	0	48	0	12	0	48	0	0	0	48	0	0		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	0	48	0	0	0	48	0	48	0	48	0	10	0	48	0	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	0	48	0	48	0	48	0	48	0	48	0	48	0	48	0	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	0	48	0	10	0	48	0	48	0	48	0	0	0	48	0	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
24		0	0	48	0	0	0	48	0	12	0	48	0	0		
26		0	0	0	0	0	0	0	0	0	0	0	0	0		
28			0	0	0	48	0	48	0	48	0	0	0			
30					0	0	0	0	0	0	0					
32																

Figure 15. GG1 Control Blade Configuration in Notches Withdrawn (SP13 and SP14)

TWA
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Critical Configuration, Statepoint 15, Cycle 5
Exposure 9280 MWd/MTU Cy 5, Moderator Temperature 140 °F, Period 103 sec.

0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
2					0	0	0	0	0	0	0					
4			0	0	48	0	24	0	48	0	48	0	0			
6		0	0	0	0	0	0	0	0	0	0	0	0	0		
8		0	48	0	0	0	48	0	48	0	0	0	48	0		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	48	0	0	0	48	0	0	0	0	0	48	0	0	0	0	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	48	0	48	0	0	0	48	0	48	0	0	0	48	0	0	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	48	0	0	0	48	0	0	0	0	0	48	0	0	0	0	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
24		0	48	0	0	0	48	0	48	0	0	0	48	0		
26		0	0	0	0	0	0	0	0	0	0	0	0	0		
28			0	0	48	0	26	0	48	0	48	0	0			
30					0	0	0	0	0	0	0					
32																

48

18

48

Critical Configuration, Statepoint 16, Cycle 6
Exposure 0 MWd/MTU Cy 6, Moderator Temperature 136 °F, Period 316 sec.

0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
2					0	0	0	0	0	0	0					
4			0	0	48	0	48	0	48	0	48	0	0			
6		0	0	0	0	0	0	0	0	0	0	0	0	0		
8		0	48	0	0	0	48	0	48	0	0	0	48	0		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	48	0	0	0	48	0	16	0	0	0	48	0	0	0	48	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	48	0	48	0	0	0	48	0	48	0	16	0	48	0	48	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	48	0	0	0	48	0	14	0	0	0	48	0	0	0	48	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
24		0	48	0	0	0	48	0	48	0	0	0	48	0		
26		0	0	0	0	0	0	0	0	0	0	0	0	0		
28			0	0	48	0	48	0	48	0	48	0	0			
30					0	0	0	0	0	0	0					
32																

Figure 16. GG1 Control Blade Configuration in Notches Withdrawn (SP15 and SP16)

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Critical Configuration, Statepoint 18, Cycle 7
Exposure 0 MWd/MTU Cy 7, Moderator Temperature 121 °F, Period 376 sec.

0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
2					0	0	0	0	0	0	0					
4			0	0	48	0	48	0	48	0	48	0	0			
6		0	0	0	0	0	0	0	0	0	0	0	0	0		
8		0	48	0	0	0	48	0	48	0	0	0	48	0		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	48	0	0	0	48	0	18	0	0	0	48	0	0	0	48	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	48	0	48	0	0	0	48	0	48	0	16	0	48	0	48	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	48	0	0	0	48	0	16	0	0	0	48	0	0	0	48	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
24		0	48	0	0	0	48	0	48	0	0	0	48	0		
26		0	0	0	0	0	0	0	0	0	0	0	0	0		
28			0	0	48	0	48	0	48	0	48	0	0			
30					0	0	0	0	0	0	0					
32																

Critical Configuration, Statepoint 19, Cycle 7
Exposure 2970 MWd/MTU Cy 7, Moderator Temperature 406.5 °F, Period 539 sec.

0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
2					0	8	0	0	0	8	0					
4			48	0	48	0	48	0	48	0	48	0	48			
6		0	0	8	0	0	0	12	0	0	0	8	0	0		
8		0	48	0	48	0	48	0	48	0	48	0	48	0		
10	0	8	0	0	0	8	0	0	0	8	0	0	0	8	0	
12	48	0	48	0	48	0	48	0	48	0	48	0	48	0	48	
14	0	0	0	8	0	0	0	8	0	0	0	8	0	0	0	
16	48	0	48	0	48	0	48	0	48	0	48	0	48	0	48	
18	0	0	0	12	0	0	0	8	0	0	0	8	0	0	0	
20	48	0	48	0	48	0	48	0	48	0	48	0	48	0	48	
22	0	8	0	0	0	8	0	0	0	8	0	0	0	8	0	
24		0	48	0	48	0	48	0	48	0	48	0	48	0		
26		0	0	8	0	0	0	8	0	0	0	8	0	0		
28			48	0	48	0	48	0	48	0	48	0	48			
30					0	8	0	0	0	8	0					
32																

Figure 17. GG1 Control Blade Configuration in Notches Withdrawn (SP18 and SP19)

TNH 9/26/03

Critical Configuration, Statepoint 20, Cycle 7
Exposure 6689 MWd/MTU Cy 7, Moderator Temperature 293 °F, Period 137 sec.

0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
2					0	0	0	0	0	0	0					
4			0	0	48	0	48	0	48	0	48	0	0			
6		0	0	0	0	0	0	0	0	0	0	0	0	0		
8		0	48	0	0	0	48	0	48	0	0	0	48	0		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	48	0	0	0	48	0	48	0	12	0	48	0	0	0	48	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	48	0	48	0	14	0	48	0	48	0	48	0	48	0	48	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	48	0	0	0	48	0	48	0	12	0	48	0	0	0	48	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
24		0	48	0	0	0	48	0	48	0	0	0	48	0		
26		0	0	0	0	0	0	0	0	0	0	0	0	0		
28			0	0	48	0	48	0	48	0	48	0	0			
30					0	0	0	0	0	0	0					
32																

Critical Configuration, Statepoint 21, Cycle 8
Exposure 0 MWd/MTU Cy 8, Moderator Temperature 140 °F, Period 160 sec.

0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
2					0	0	0	0	0	0	0					
4			0	0	48	0	32	0	48	0	48	0	0			
6		0	0	0	0	0	0	0	0	0	0	0	0	0		
8		0	48	0	0	0	48	0	48	0	0	0	48	0		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	48	0	0	0	48	0	0	0	0	0	48	0	0	0	48	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	48	0	48	0	0	0	48	0	48	0	0	0	48	0	32	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	48	0	0	0	48	0	0	0	0	0	48	0	0	0	48	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
24		0	48	0	0	0	48	0	48	0	0	0	48	0		
26		0	0	0	0	0	0	0	0	0	0	0	0	0		
28			0	0	48	0	34	0	48	0	48	0	0			
30					0	0	0	0	0	0	0					
32																

Figure 18. GG1 Control Blade Configuration in Notches Withdrawn (SP20 and SP21)

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Critical Configuration, Statepoint 22, Cycle 8
Exposure 0 MWd/MTU Cy 8, Moderator Temperature 178 °F, Period 108 sec.

0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
2					0	0	0	0	0	0	0					
4			0	0	48	0	48	0	48	0	48	0	0			
6		0	0	0	0	0	0	0	0	0	0	0	0	0		
8		0	48	0	0	0	48	0	48	0	0	0	48	0		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	48	0	0	0	48	0	0	0	0	0	48	0	0	0	48	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	48	0	48	0	0	0	48	0	48	0	0	0	48	0	48	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	48	0	0	0	48	0	34	0	0	0	48	0	0	0	48	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
24		0	48	0	0	0	48	0	48	0	0	0	48	0		
26		0	0	0	0	0	0	0	0	0	0	0	0	0		
28			0	0	48	0	48	0	48	0	48	0	0			
30					0	0	0	0	0	0	0					
32																

Critical Configuration, Statepoint 23, Cycle 8
Exposure 480 MWd/MTU Cy 8, Moderator Temperature 229 °F, Period 118 sec.

0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
2					0	0	0	0	0	0	0					
4			0	0	48	0	48	0	48	0	48	0	0			
6		0	0	0	0	0	0	0	0	0	0	0	0	0		
8		0	48	0	0	0	48	0	48	0	0	0	48	0		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	48	0	0	0	48	0	48	0	48	0	48	0	0	0	48	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	48	0	48	0	0	0	48	0	48	0	0	0	48	0	48	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	48	0	0	0	48	0	48	0	24	0	48	0	0	0	48	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
24		0	48	0	0	0	48	0	48	0	0	0	48	0		
26		0	0	0	0	0	0	0	0	0	0	0	0	0		
28			0	0	48	0	48	0	48	0	48	0	0			
30					0	0	0	0	0	0	0					
32																

Figure 19. GG1 Control Blade Configuration in Notches Withdrawn (SP22 and SP23)

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6. MCNP MODEL

6.1 MCNP GEOMETRY

The geometry for the MCNP analysis uses the dimensions from Tables 2 through 9. The geometry starts with modeling an assembly in the x-y direction with the fuel rods shown discretely (fuel + clad + water) in either an 8x8 or 9x9 lattice with all the fuel rods for a particular fuel rod array (8x8 or 9x9) having the same dimensions. Both uranium only and also Gadolinia bearing fuel rod dimensions are averaged to arrive at the final radial dimensions for the discrete fuel rods. The SAS2H model used in Reference 2 to deplete the fuel for isotopics was for a smeared assembly and there is no reason to have different size fuel rod in the MCNP runs. The fuel inside the clad was also smeared to the inside of the clad. This omitted the pellet-clad gap. The fuel density was revised to accommodate this pellet size increase. The fuel rod array was set-up to allow the Gadolinia bearing fuel rods and the uranium only fuel rods to be in different locations.

The water rods were modeled using their actual size and the spacer capture rods (SCR) were modeled to be the same as the water rods. This was done for both the 8x8 and 9x9 assemblies. The fuel rod and water rod array was surrounded with a thin gap of water to account for the fuel rod array being slightly smaller than the inside of the channel/can that surrounds the fuel array. The zircaloy channel was modeled discretely. The water gap surrounding the fuel assemblies was split in half. This means that the control blade was also split in half. Each fuel assembly has a control blade around one corner of the assembly depending on whether the control blade is inserted. Figure 3 showed how the control blade fits between the assemblies. The MCNP model was developed to have geometric cells include half of the homogenized control blade with each fuel assembly. The control blade can be inserted by assigning the control rod materials to the blade cells. By assigning water to those cells the control blade is withdrawn. Figures 20 through 27 describe the layout of the 8x8 and 9x9 fuel assemblies.

The axial height of an assembly block was made 15.24 centimeters or 6 inches. The original depletion data for the fuel that was received from Grand Gulf had the fuel assemblies divided into 25 equal axial nodes of 6 inches each. In Reference 3, when summarizing the GG1 data, the 25 nodes were consolidated into 10 nodes to limit the amount of data that had to be handled. The reduction to 10 nodes used multiples of the original 25 nodes. Not all fuel types had the same dimensions for the 10 nodes. This means that fuel type A had different nodal dimensions than a type F which in turn was different from a type H. There were four different axial nodal spacing for the fuel used in cycles 2 through 8 of GG1. Figure 28 shows the variation in nodal spacing. Figure 28 shows that by using an assembly block with an axial height of 15.24 centimeters or 6 inches that all four nodal spacings can be handled by simply stacking the fuel axial blocks into a 25 high array to obtain the desired 10 unique nodes. Because the control blades are moved in minimum 6 inch increments (two notches) this model with 6 inch axial blocks can easily accommodate any full or partial blade insertion. Axial assembly blocks have different cell and universe numbers in the MCNP model so that each blocks can have different fuel compositions to account for axial burnup differences and different control blade compositions to achieve blade-in and blade-out conditions. The blocks were modeled to allow two fuel rod types

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(uranium only and Gadolinia bearing rods) and water rods. The x-y arrangements of the different rods are easily changed using the fuel rod lattice description in the MCNP input for each assembly in any axial block/node. Figures 31 through 36 show the different standard Gadolinia fuel rod patterns used in the 8x8 and 9x9 fuel assemblies. In Reference 12, Figures 4.24 and 4.25 gave the standard Gadolinia rod patterns for the 9x9 fuel assemblies. Standard patterns for the 8x8 Gadolinia rod positions were developed based on the the 9x9 Gad rod patterns. The numbers of Gadolinia fuel rods in each fuel batch type are shown in Tables 21 through 27 and were taken from Tables 15 through 20 of Reference 2. The same block description can be used more than once in the stack to construct the nodes that are more than a single block high.

After constructing all the different fuel assemblies needed in the core by stacking the axial blocks to make up the 10 axial nodes, the half core can then be assembled using these fuel assemblies in an x-y lattice containing 400 assemblies that have an axial height equal to the active fuel height.

Figure 29 demonstrates how the assemblies fit together in a node using a simple 2x2 array with the control blade in the center. Core configurations of quarter core, half core, or even full core can be constructed if enough unique assembly geometries are compiled in the MCNP input. Figure 30 is an axial slice through the core and shows the regions above and below and to the side of the fuel region. Because the 8x8 and 9x9 fuel assemblies have the same outer dimensions the two fuel assembly types can be inter-mingled in the core. The half core geometry containing 400 assemblies was used in the MCNP reactivity analyses to perform the 16 statepoints for GG1 because half core geometry was considered necessary to adequately model the non-symmetric control blade patterns that were used at the various statepoints.

6.2 MCNP SAMPLE GEOMETRY INPUT

The final MCNP input deck is too long to list in this report after all the geometry is complete and the mixtures cards added. The reader must go to the COLD listing for the complete input decks. The final input deck for a statepoint is more then 307,000 lines long. A sample of the card input necessary to describe the geometry for a unit block or node is listed below to demonstrate the MCNP cards necded to describe just one axial block for one fuel assembly.

```
c BWR 8x8 Control Blade Upper Left Corner
c
c  u=1 for Water Rod
c
20   40  -0.98897   -10        u=1 imp:n=1 $ water
21   11  -6.56   +10 -11    u=1 imp:n=1 $ clad
22   40  -0.98897   +11        u=1 imp:n=1 $ water around tube
c
c  u=2 for fuel rod
c
23  6001  -9.78  -10       u=2 imp:n=1 $ fuel rod
24  11  -6.56   +10 -11     u=2 imp:n=1 $ cladding
25  40  -0.98897   +11         u=2 imp:n=1 $ water around fuel rod
```

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```
c
523  6002 -9.60  -10      u=6 imp:n=1 $ Gd fuel rod
524  11  -6.56   +10 -11    u=6 imp:n=1 $ cladding
525  40  -0.98897   +11        u=6 imp:n=1 $ water around fuel rod
c
26  40  -0.98897  (-50 45 -46 42):(-41 45 -46 52)  u=101 imp:n=1 $blade UL
27  40  -0.98897  -51 50 -46 42                    u=101 imp:n=1 $blade
28  40  -0.98897  -41 45 -52 53                    u=101 imp:n=1 $blade
c
c  u=3 for fuel rod lattice
c
29  0    -20 +21 -22 +23 lat=1 u=3 imp:n=1 fill=-4:3 -4:3 0:0
      2 2 2 2 2 2 2 2
      2 2 6 2 2 6 2 2
      2 6 2 2 2 2 6 2
      2 2 2 2 1 2 2 2
      2 2 2 1 2 2 2 2
      2 6 2 2 2 2 6 2
      2 2 6 2 2 6 2 2
      2 2 2 2 2 2 2 2
c
c u=4 to cut out rod array with u=3 and surround with h2o & Zr channel
c
30  0        -24 +25 -26 +27   fill=3  imp:n=1  u=4 $ 8x8 Lattice
31  40  -0.98897   (24:-25:26:-27) -30 +31 -32 +33    u=4  imp:n=1  $Water
32  51  -6.56   (30:-31:32:-33)                u=4  imp:n=1  $Zr Can
c
33  0        -34 35 -36 37  fill=4  u=5 imp:n=1
34  40  -0.98897   (34:-35:36:-37)       u=5 imp:n=1  $Water in Gap to blade
c
35  0        -40 41 -42 43  fill=5        u=101 imp:n=1
36  40  -0.98897   (40:-41:42:-43) #26 #27 #28    u=101 imp:n=1  $Water + Blade
```

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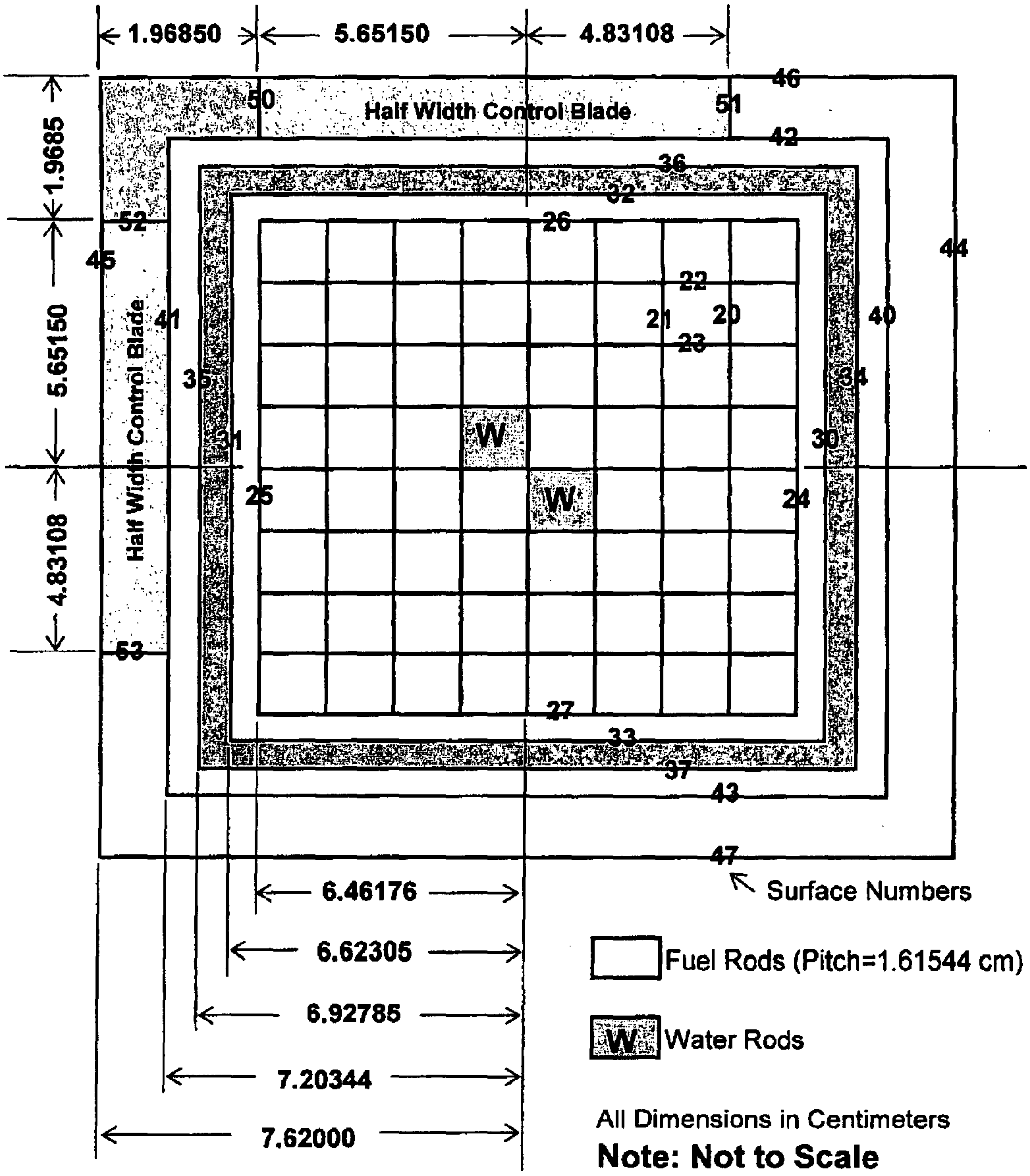
Figure 20. BWR 8x8 Assembly – Control Upper Left



All Dimensions in Centimeters

Note: Not to Scale

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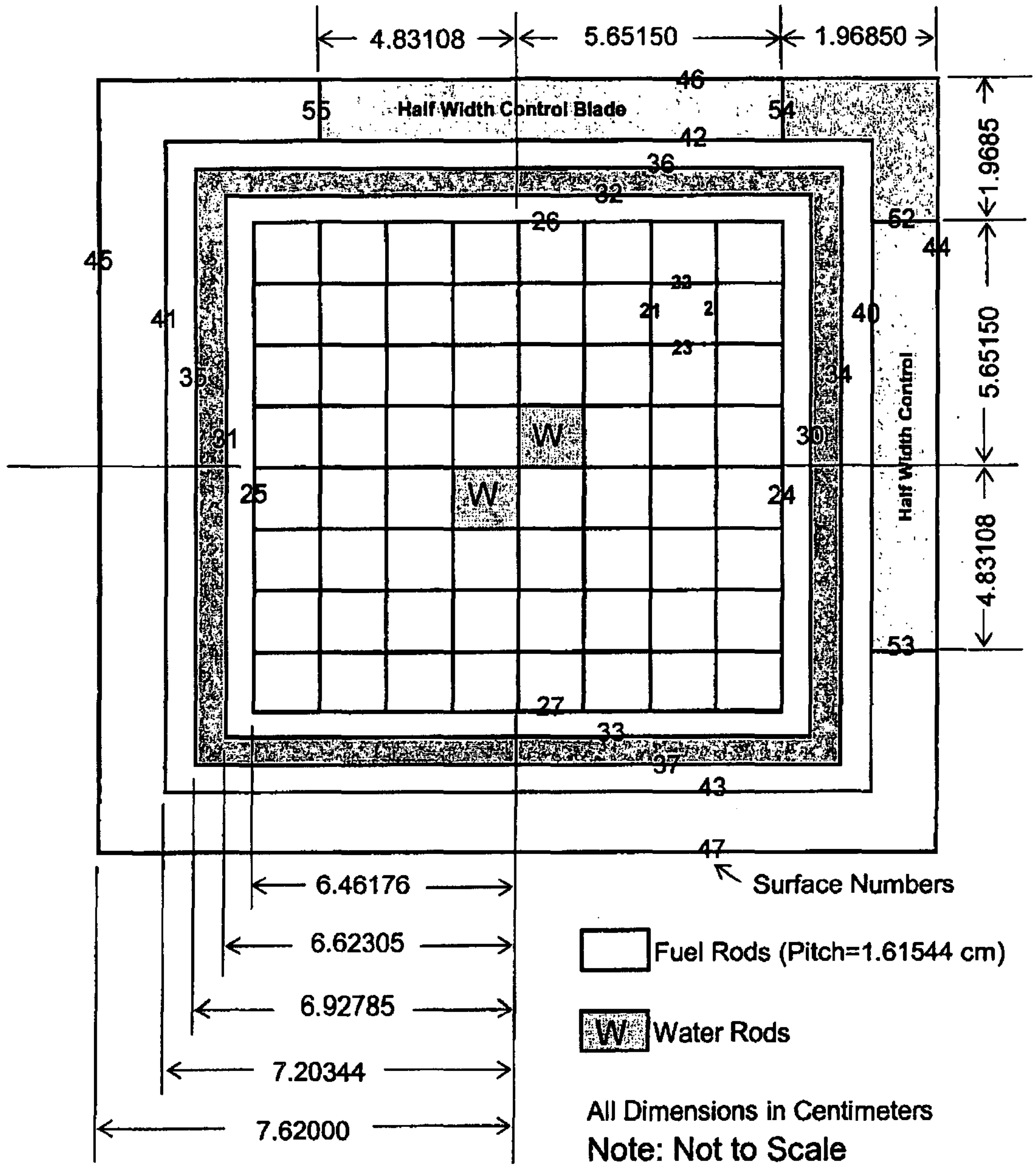
Figure 21. BWR 8x8 Assembly – Control Upper Right



All Dimensions in Centimeters

Note: Not to Scale

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Figure 22. BWR 8x8 Assembly – Control Lower Right

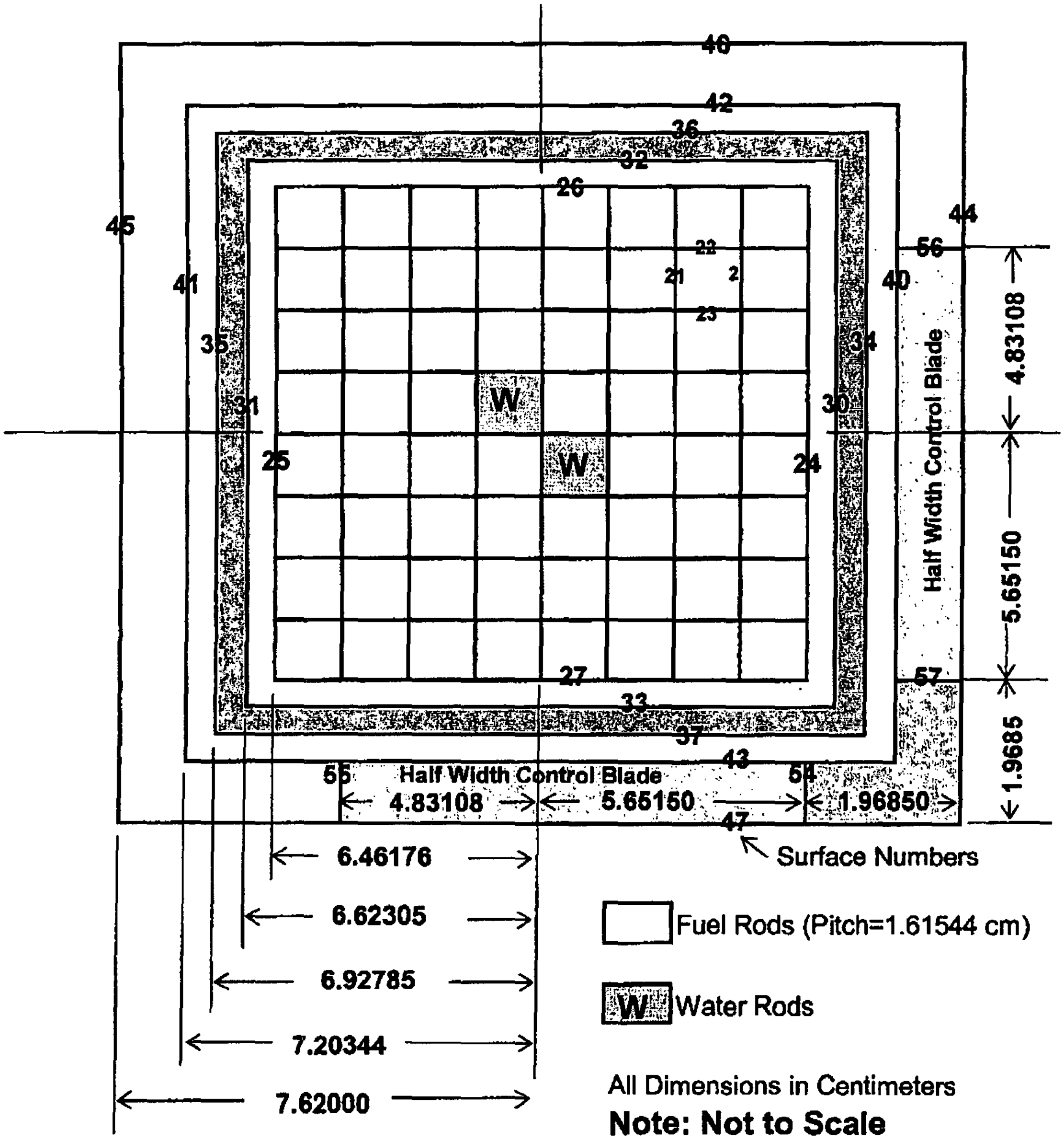

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Figure 23. BWR 8x8 Assembly – Control Lower Left

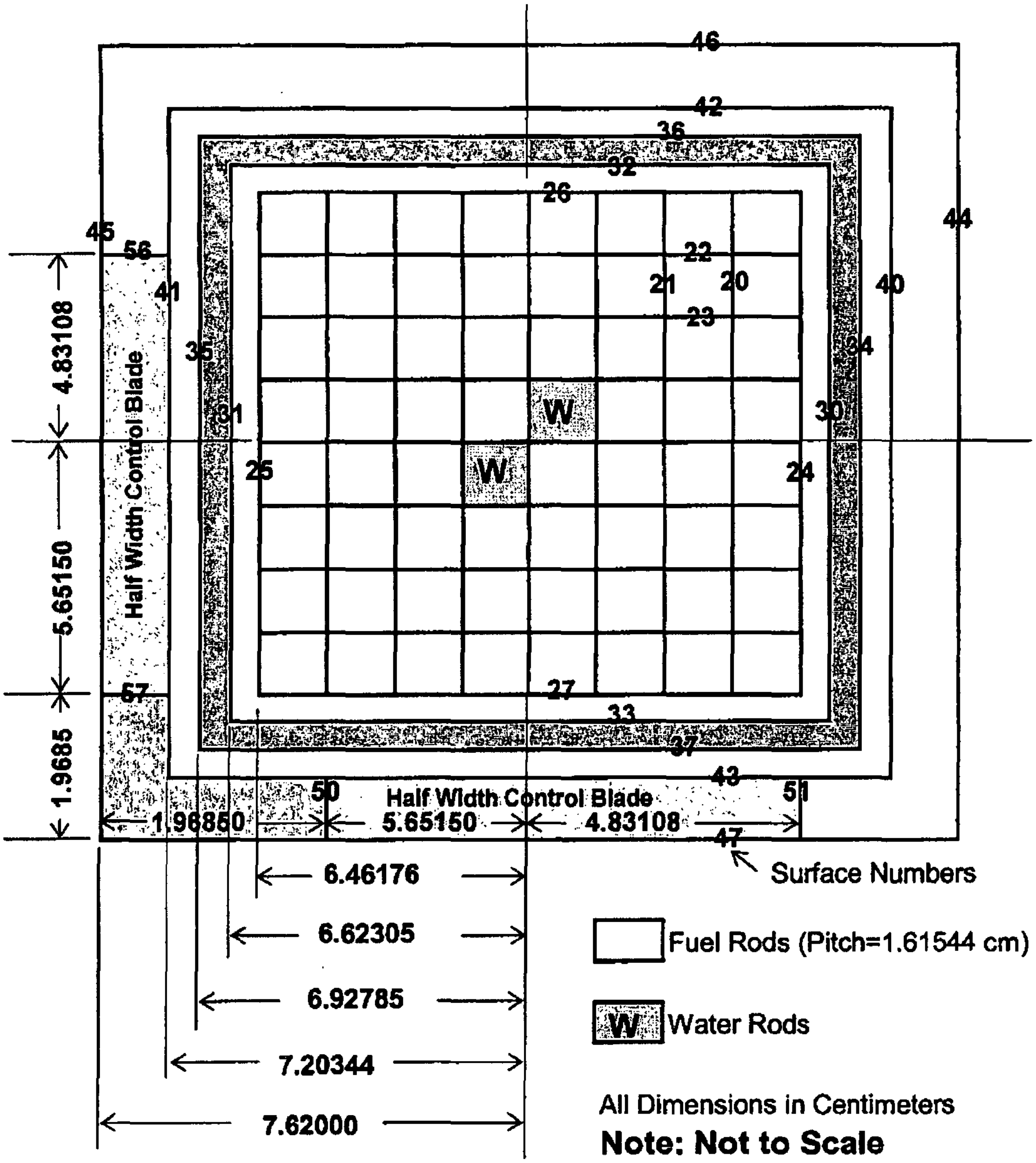

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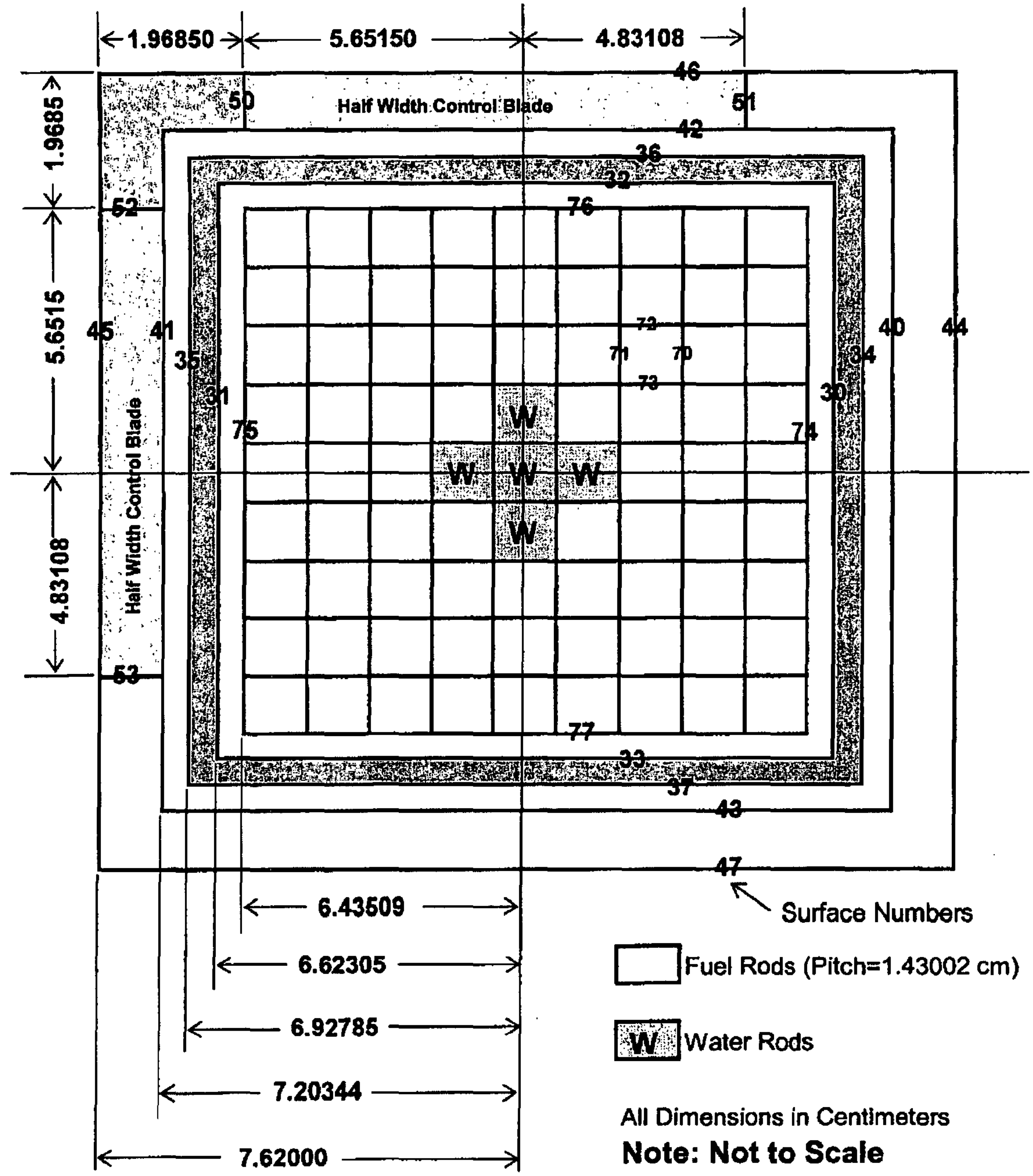
Figure 24. BWR 9x9 Assembly – Control Upper Left



All Dimensions in Centimeters

Note: Not to Scale

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Figure 25. BWR 9x9 Assembly – Control Upper Right

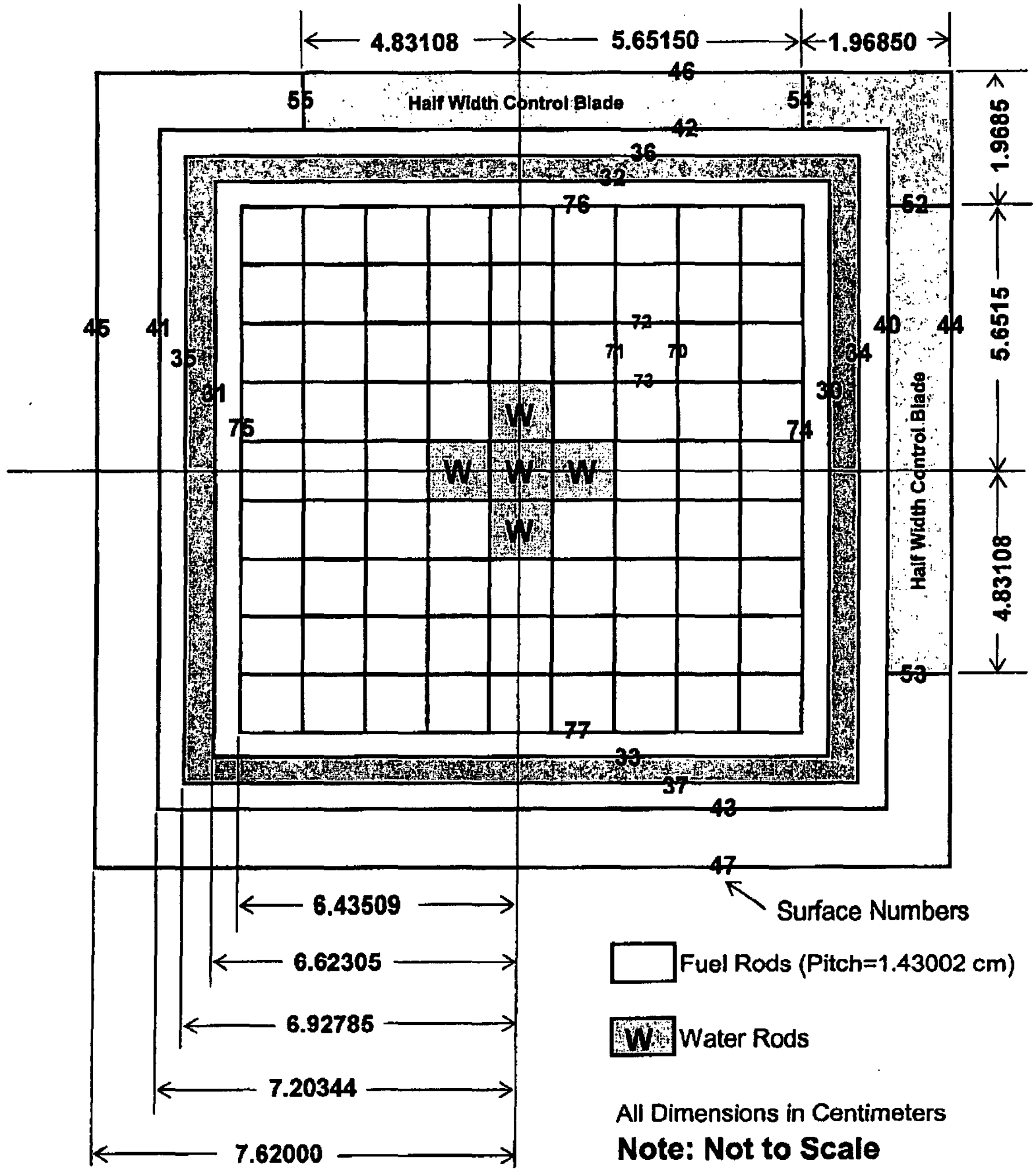

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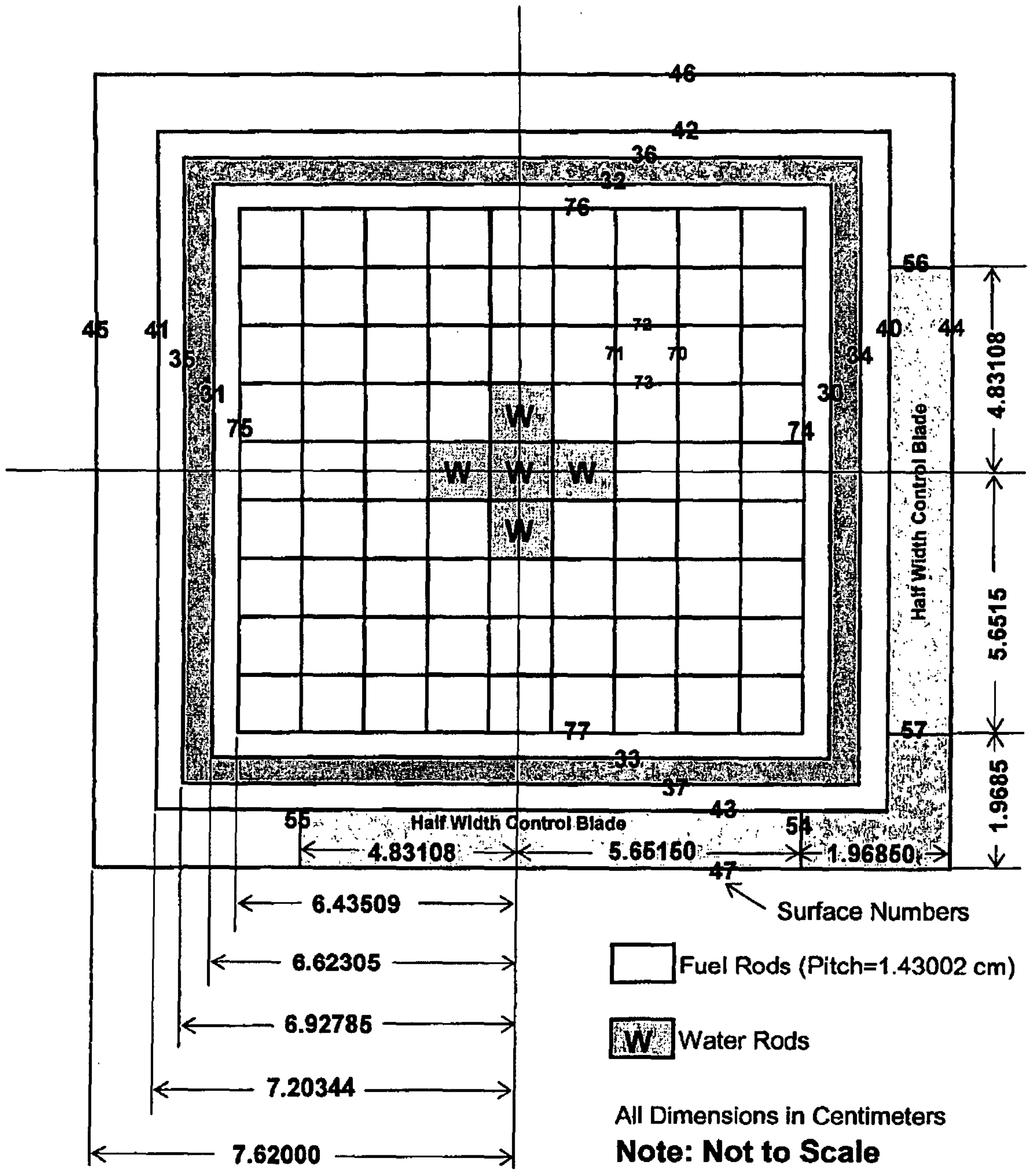
Figure 26. BWR 9x9 Assembly – Control Lower Right



All Dimensions in Centimeters

Note: Not to Scale

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Figure 27. BWR 9x9 Assembly – Control Lower Left

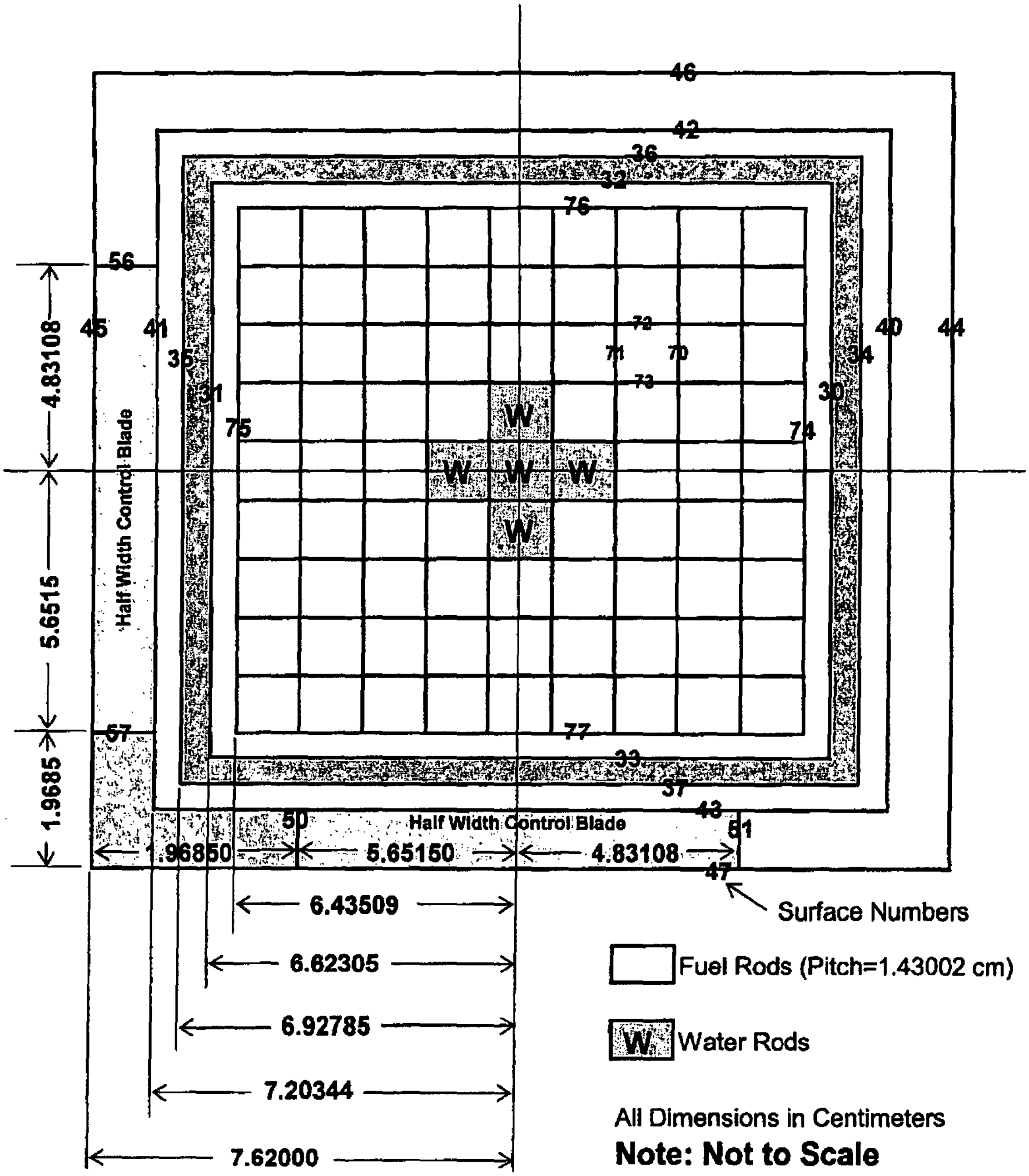

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Figure 28. Collapsed 10 Axial Nodes Description for GG1 Assemblies

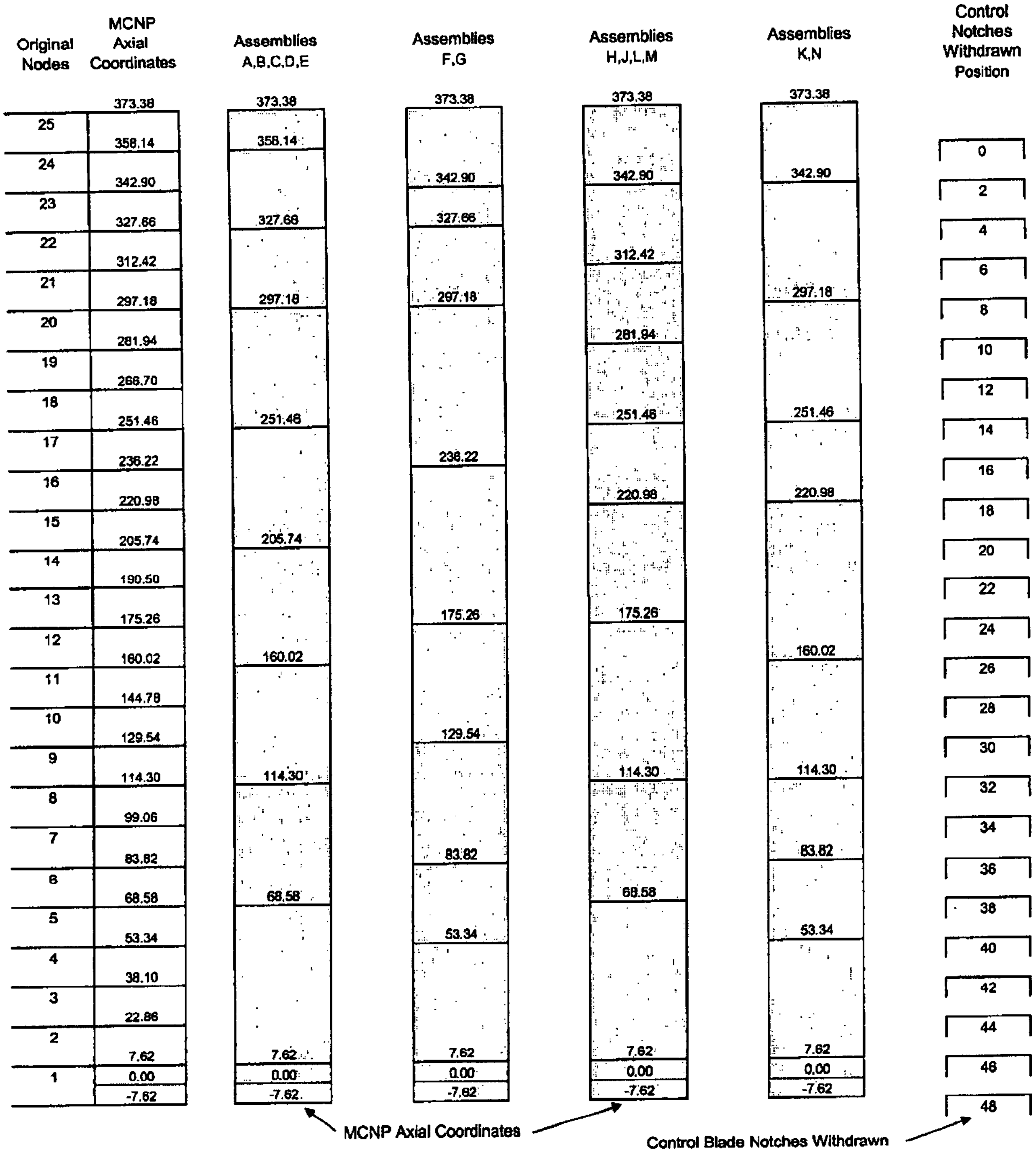

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Figure 29. BWR 9X9 Four Assembly Array

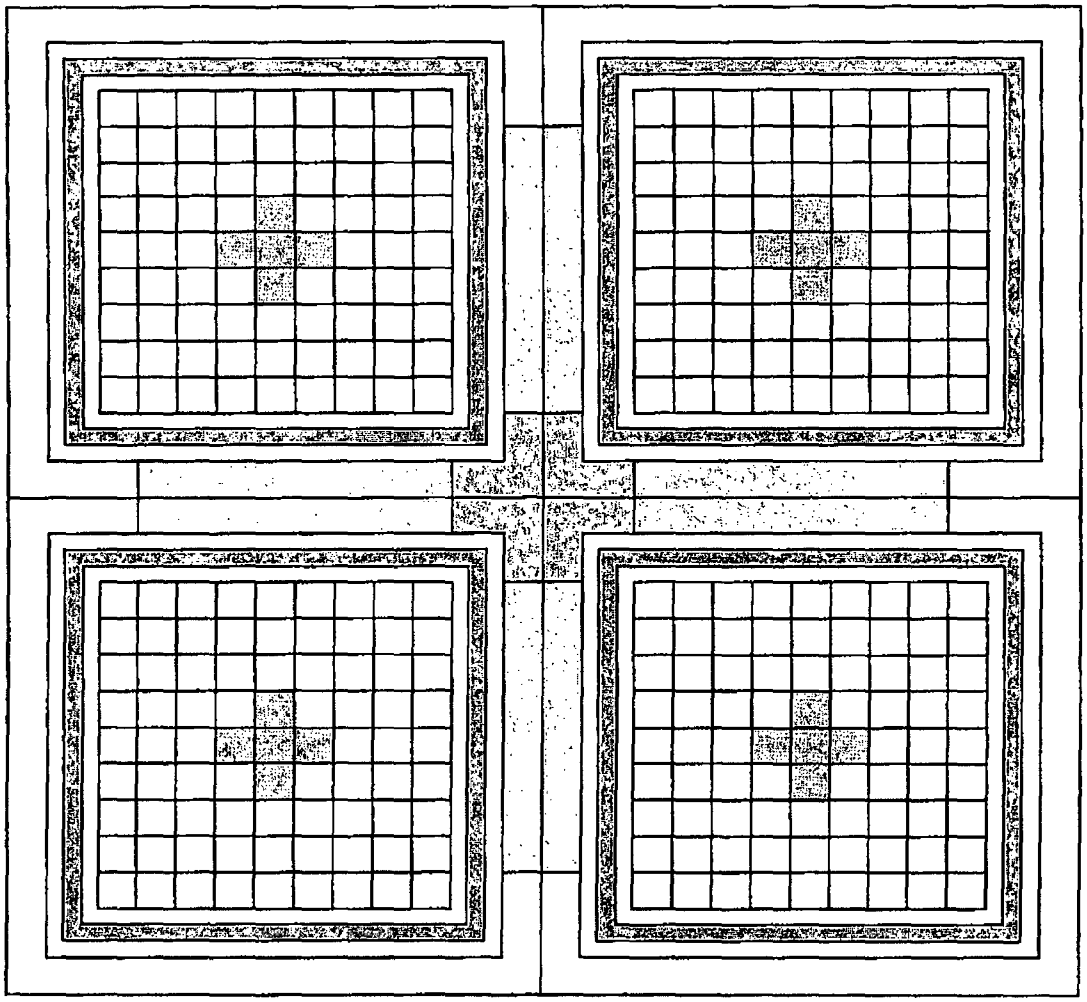

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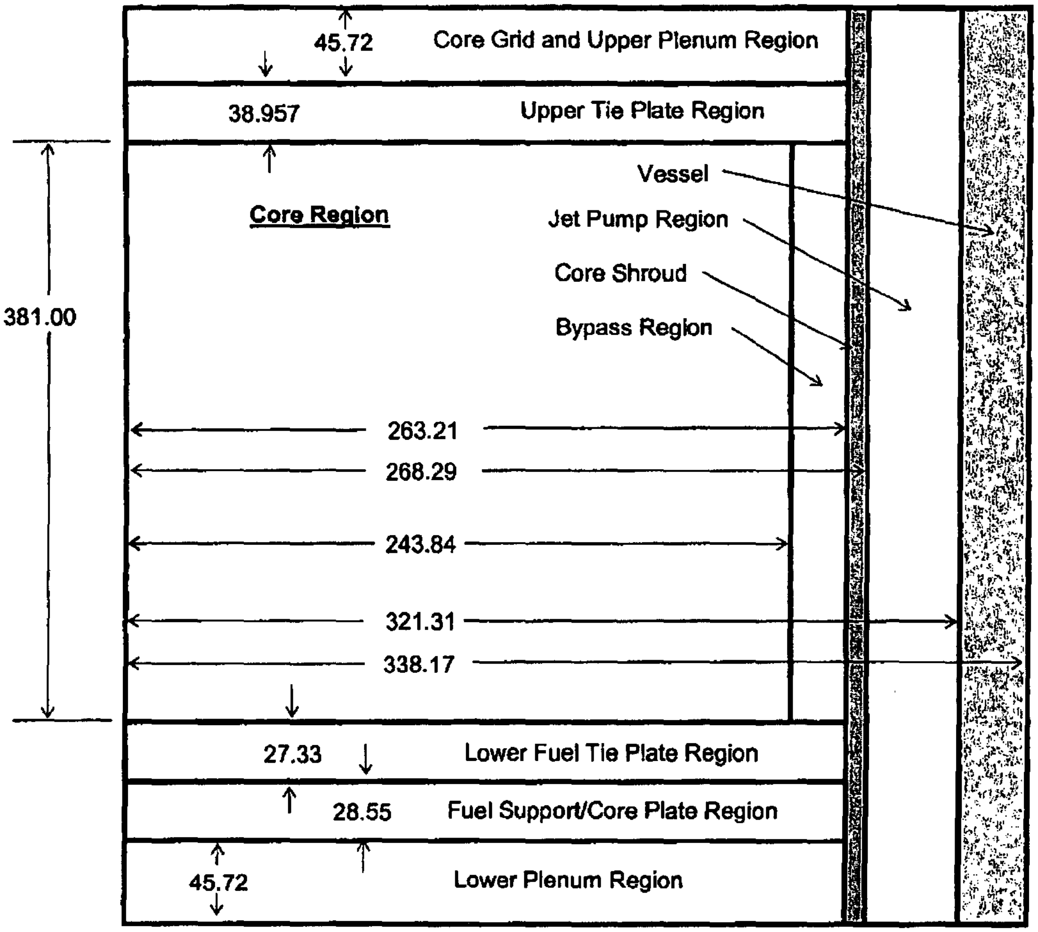
Figure 30. MCNP Model for GG1 BWR - Axial Slice



Note: All Dimensions in Centimeters

NOT TO SCALE

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Figure 31. Standard Gadolinia Fuel Rod Lattice Map for 9X9-8 GAD Rods ✓

CONTROL CORNER	1	2	3	4	5	6	7	8	9
1									
2			8				8		
3		8						8	
4					▨				
5				▨	▨	▨			
6					▨				
7		8						8	
8			8				8		
9									

Figure 32. Standard Gadolinia Fuel Rod Lattice Map for 9X9-9 GAD Rods ✓

CONTROL CORNER	1	2	3	4	5	6	7	8	9
1									
2		9			9			9	
3									
4					▨				
5		9		▨	▨	▨		9	
6					▨				
7								9	
8		9			9		9		
9									

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Figure 33. Standard Gadolinia Fuel Rod Lattice Map For 9X9-10 GAD Rods

CONTROL CORNER	1	2	3	4	5	6	7	8	9
1									
2			10		10			10	
3		10							
4					▨				
5		10		▨	▨	▨		10	
6					▨				
7								10	
8		10			10		10		
9									

Figure 34. Standard Gadolinia Fuel Rod Lattice Map For 8x8-5 GAD Rods

CONTROL CORNER	1	2	3	4	5	6	7	8
1								
2		5					5	
3								
4				▨				
5					▨			
6							5	
7		5				5		
8								

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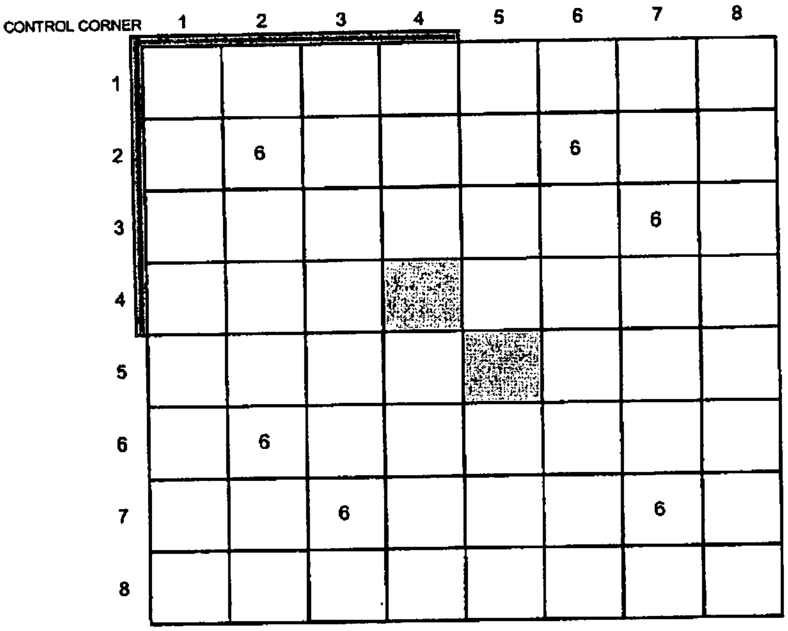
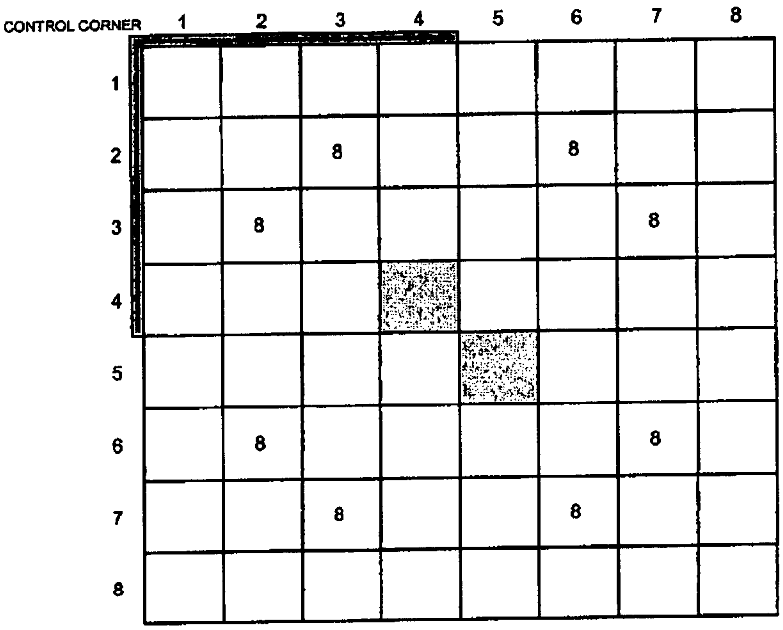
Figure 35. Standard Gadolinia Fuel Rod Lattice Map For 8x8-6 GAD Rods ✓



CONTROL CORNER	1	2	3	4	5	6	7	8
1								
2		6				6		
3							6	
4				▨				
5					▨			
6		6						
7			6				6	
8								

Figure 36. Standard Gadolinia Fuel Rod Lattice Map For 8x8-8 GAD Rods



CONTROL CORNER	1	2	3	4	5	6	7	8
1								
2			8			8		
3		8					8	
4				▨				
5					▨			
6		8					8	
7			8			8		
8								

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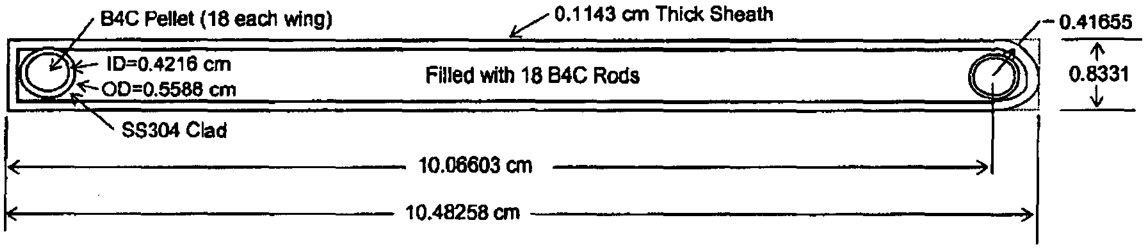
6.3 MCNP NON-FUEL MATERIALS

The fuel mixtures were obtained from the Reference 2 depletion calculations that were done for each node of each assembly in one-eighth core. The one-eighth core isotopics were used in the expanded half core MCNP calculation by using symmetry. The fuel for each node was depleted in Reference 2 using the core follow history data given in Reference 3. The isotopes transferred from Reference 2 for the burned fuel matched those used in earlier MCNP calculations such as performed in Reference 10 for the Quad Cities Unit 2 reactor.

The non-fuel materials in the MCNP model are mixtures that do not change with depletion. The fuel cladding, the channel or can, the core shroud, the core pressure vessel, the mixtures above and below the active fuel, and the homogenized control blade are mixtures that do not change with fuel depletion. There was not enough information in Reference 3 to determine the mixtures above and below the active fuel. Therefore, these mixtures and thicknesses were obtained from the Quad Cities reactivity calculations done in Reference 10. The shroud, the control blade center section, and cladding for the B4C pellets in the control blades are standard stainless steel 304. The core pressure vessel was also modeled as SS304 for simplicity. The vessel is far from the fuel and its influence on the core is almost negligible, so using SS304 as the vessel material does not introduce any significant error in the reactivity calculations. Isotopics for SS304 were taken from Reference 11. The zircaloy-2 and zircaloy-4 compositions for the fuel cladding, the water rod cladding, and the channel surrounding the fuel array were also from Reference 11.

6.4 HOMOGENIZED CONTROL BLADE MIXTURE

The wing part of the control blade that contained the SS clad B4C pellets was homogenized allowing it to be split in half making the control blade's geometrical configuration in the MCNP simpler. The control blade is so "black" to neutrons that the homogenization of the blade will have no effects on the reactivity calculations. The part of the blade that is homogenized is shown below. The full control blade has 4 of these wings that contain 18 B4C rods in each wing giving a total of 72 rods in the complete control blade. The area that is not occupied by the outer SS304 sheath or the B4C rods is filled with water. The rod is squared off on the outside end.



The volume fractions of each type of material will be calculated.

Total wing area = $(10.48258)(0.8331) = 8.733037\ \text{cm}^2$
Sheath area = $(0.6045)(0.1143) + (10.06603)(0.1143)(2) + \Pi/2(0.41655^2 - 0.30225^2)$
= $2.499244\ \text{cm}^2$
B4C area = $\Pi/4(0.4216)^2(18) = 2.51283\ \text{cm}^2$

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Clad area = $\Pi/4(0.5588^2 - 0.4216^2)(18) = 1.901603\ cm^2$

Volume Fraction B4C = 2.51283/8.733037 = 0.287738

Volume Fraction SS304 = (1.901603 +2.40245)/8.733037 = 0.492847

Volume Fraction Water = (1.0 - 0.287738 - 0.492847) = 0.219415

B4C Density = (0.70) (2.52) = 1.764 g/cm^3 (B4C Theoretical Density from Reference 14)

SS304 Density = 7.94 g/cm^3

Water Density = 0.98135 g/cm^3

Table 28 below give a spread sheet calculating the material densities for the homogenized blade.

Table 28. Spread Sheet giving Homogenized Control Blade Materials

	Iso or Elem	Xsect ID	Atom Abund.	Mol Wt.	Iso Wt Fract	Matl Wt%	Matl g/CC	Mix g/CC	Mix wt %
SS304	C	6012.50C	98.9	12.011	1.000	0.080	0.006352	0.003131	0.067526
	N	7014.50C	99.63	14.0067	1.000	0.100	0.00794	0.003913	0.084407
	Si	14000.50C	100	28.0855	1.000	1.000	0.0794	0.039132	0.844073
	P	15031.50C	100	30.973762	1.000	0.045	0.003573	0.001761	0.037983
	S	16032.50C	95.02	32.07	1.000	0.030	0.002382	0.001174	0.025322
	Cr-50	24050.60C	4.345	49.946047	0.042	0.793	0.06296425	0.031032	0.66935
	Cr-52	24052.60C	83.79	51.940511	0.837	15.903	1.2627039	0.62232	13.42335
	Cr-53	24053.60C	9.5	52.940652	0.097	1.838	0.1459204	0.071916	1.551228
	Cr-54	24054.60C	2.365	53.938884	0.025	0.466	0.03701146	0.018241	0.393456
	Mn-55	25055.50C	100	54.938048	1.000	2.000	0.1588	0.078264	1.688146
	Fe-54	26054.60C	5.9	53.939613	0.057	3.903	0.30993034	0.152748	3.294759
	Fe-56	26056.60C	91.72	55.93494	0.919	62.926	4.9963341	2.462428	53.11424
	Fe-57	26057.60C	2.1	56.935396	0.021	1.467	0.11644099	0.057388	1.237843
	Fe-58	26058.60C	0.28	57.933278	0.003	0.199	0.01579757	0.007786	0.167938
	Ni-58	28058.60C	68.27	57.935346	0.674	6.234	0.49497954	0.243949	5.261951
	Ni-60	28060.60C	26.1	59.930788	0.267	2.465	0.19575111	0.096475	2.08096
	Ni-61	28061.60C	1.13	60.931058	0.012	0.109	0.0086165	0.004247	0.091599
	Ni-62	28062.60C	3.59	61.928346	0.038	0.350	0.0278226	0.013712	0.295772
	Ni-64	28064.60C	0.91	63.927968	0.010	0.092	0.00728025	0.003588	0.077394
					Totals	100	7.94	3.913205	84.4073
B4C	B10	5010.50C	19.9	10.0129372	0.184	14.4245	0.25444881	0.073215	1.579229
	B11	5011.56C	80.1	11.0093056	0.816	63.8381	1.12610347	0.324023	6.989127
	C	6012.50C	98.9	12.011	1.000	21.7374	0.38344772	0.110332	2.379857
					Totals	100	1.764	0.50757	10.94821
H2O	H	1001.50C	98.985	1.0079	1.000	11.1894	0.10980757	0.024093	0.519692
	O	8016.50C	99.76	15.9994	1.000	88.8106	0.87154243	0.191229	4.124794
					Totals	100	0.9813500	0.215323	4.644486
					Final Homogeneous Density =			4.636098	100

Note: Isotopic abundances were taken from Reference 13

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All the non-fuel mixtures used in the MCNP are listed in Table 29 which is a listing from the MCNP input for the various materials.

Table 29. MCNP Listing of the Non-fuel Mixtures

```
C   MATERIAL SPECIFICATIONS
C
C  Stainless Steel, B4C, and Water homogenized for the Control Blade Wings
C
M0008    6012.50c  -2.447382    7014.50c    -0.084407  $ B4C for Blades
        14000.50c  -0.844073   15031.50c    -0.037983
        16032.50c  -0.025322   24050.60c    -0.669350
        24052.60c  -13.42335   24053.60c    -1.551228
        24054.60c  -0.393456   25055.50c    -1.688146
        26054.60c  -3.294759   26056.60c    -53.11424
        26057.60c  -1.237843   26058.60c    -0.167938
        28058.60c  -5.261951   28060.60c    -2.080960
        28061.60c  -0.091599   28062.60c    -0.295772
        28064.60c  -0.077394    5010.50c    -1.579229
         5011.56c  -6.989127    8016.50c     -4.124794
         1001.50c  -0.519692
C
C   Zircaloy-2 for Fuel Rod Cladding
C
M0011   8016.50C -0.12   24050.60C -0.004 24052.60C -0.084  $ ZIRC-2 CL
      24053.60C -0.01    24054.60C -0.002 26054.60C -0.006
      26056.60C -0.0918 26057.60C -0.002 26058.60C -0.0003
      28058.60C -0.0337 28060.60C -0.013 28061.60C -0.0006
      28062.60C -0.0019 28064.60C -0.005 40000.60C -98.230
      50000.35C -1.4
C
C  Water for Moderator, Radial Reflector, and Upper/Lower Plenum Regions
C
M0040  1001.50C  -11.1894                          $ MODERATOR
       8016.50C  -88.8106
MT0040 LWTR.01
C
C  Zircaloy-4 for Channel/Can around Assembly
C
M0051   8016.50C -0.12   24050.60C -0.004 24052.60C -0.084  $ ZIRC-4 CH
      24053.60C -0.01     24054.60C -0.002  26054.60C -0.011
      26056.60C -0.184    26057.60C -0.004 26058.60C -0.0006
      40000.60C -98.180   50000.35C -1.4
C
C   Stainless Steel 304 for Control Blade, Shroud, and Pressure Vessel
C
M0070  6000.50C -0.080  7014.50C  -0.1000 14000.50C -1.000  $ SS304 SHR
      15031.50C -0.045   16032.50C -0.03    24050.60C -0.793
      24052.60C -15.903 24053.60C -1.838  24054.60C -0.466
      25055.50C -2.0     26054.60C -3.903  26056.60C -62.926
      26057.60C -1.467   26058.60C -0.199  28058.60C -6.234
      28060.60C -2.465   28061.60C -0.109  28062.60C -0.350
      28064.60C -0.092
C
```

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```
C  Homogenized Mixture for the Upper Tie Plate Region
C
M0080  6000.50C  -0.037  7014.50C  -0.047  14000.50C  -0.349  $ SS304 ZIR
       15031.50C -0.021  16032.50C -0.014  24050.60C  -0.370
       24052.60C -7.422  24053.60C -0.858  24054.60C  -0.218
       25055.50C -0.932  26054.60C -1.827  26056.60C  -29.447
       26057.60C -0.686  26058.60C -0.093  28058.60C  -2.905
       28060.60C -1.149  28061.60C -0.051  28062.60C  -0.163
       28064.60C -0.043  8016.50C  -35.425  1001.50C  -4.426
       40000.60C -13.337 50000.35C -0.190
C
C  Homogenized Mixture for the Lower Tie Plate Region
C
M0090  6000.50C  -0.057   7014.50C  -0.071  14000.50C  -0.535  $ SS304 ZIR
       15031.50C -0.032    16032.50C -0.021  24050.60C  -0.566
       24052.60C -11.353   24053.60C -1.312  24054.60C  -0.333
       25055.50C -1.427    26054.60C -2.796  26056.60C  -45.077
       26057.60C -1.051  26058.60C  -0.143  28058.60C  -4.449
       28060.60C -1.759  28061.60C  -0.077  28062.60C  -0.250
       28064.60C -0.065   8016.50C  -22.167  1001.50C  -2.770
       40000.60C -3.637  50000.35C  -0.052
C
C  Homogenized Mixture for the Lower Core Support Region
C
M0091  6000.50C  -0.071 7014.50C  -0.089  14000.50C  -0.667  $ SS304 H2O
       15031.50C -0.040  16032.50C -0.027  24050.60C  -0.705
       24052.60C -14.146 24053.60C -1.635  24054.60C  -0.415
       25055.50C -1.779  26054.60C -3.485  26056.60C  -56.178
       26057.60C -1.309  26058.60C -0.178  28058.60C  -5.545
       28060.60C -2.193  28061.60C -0.097  28062.60C  -0.312
       28064.60C -0.082   1001.50C -1.237   8016.50C  -9.813
```

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7. RESULTS

The MCNP calculations were performed for the sixteen statepoints for the Grand Gulf Unit 1 BWR and the resulting effective multiplication factors (K_{eff}) are tabulated in Table 30. The Average Energy of Neutron Causing Fission (AENCF) is also tabulated for each case. The AENCF is defined as the energy loss to fission divided by the neutron weight taken from the neutron balance tables in the MCNP output. The Uranium isotopes U-235 and U-238 cross sections are available in the MCNP library at either 294 degrees Kelvin or 587 degrees Kelvin. The actual moderator/fuel temperature varies between 111 degrees Fahrenheit and 406.5 degrees Fahrenheit (317 °K to 481 °K). The higher temperature of 587 Kelvin was used for all calculations except for statepoint 5 which was run at both temperatures. In Table 30, it can be seen that the higher temperature gives a more conservative K_{eff} for criticality safety than the lower temperature.

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Table 30. MCNP Results For Grand Gulf Unit 1 Reactivity Analysis

Statepoint	Burnup (MWd/MTU)	EFPD	Moderator Temperature (°F)	Moderator Density g/cm^3	K_{eff}	Sigma	AENCF
Cycle 4							
SP5	0	0	148.5	0.98897	0.99554	0.0001	0.173732
SP5a*	0	0	148.5	0.98897	1.00118	0.0001	0.172746
SP6	109	4.01	188	0.97393	0.99324	0.0001	0.176229
SP7	1998	73.49	221	0.96018	0.99296	0.0001	0.178494
Cycle 5							
SP10	0	0	111	1.00191	0.99461	0.0001	0.173252
SP11	451	16.54	180	0.97710	0.99810	0.0001	0.176283
SP12	4042	148.27	225.5	0.95823	0.98685	0.0001	0.181266
SP13	4506	165.29	209	0.96531	0.98551	0.0001	0.181162
SP14	5550	203.58	174	0.97944	0.98295	0.0001	0.180717
SP15	9280	340.41	140	0.99201	0.98309	0.0001	0.181072
Cycle 6							
SP16	0	0	136	0.99342	0.99875	0.0001	0.172694
Cycle 7							
SP18	0	0	121	0.99858	0.98993	0.0001	0.173256
SP19	2970	108.81	406.5	0.85967	0.98249	0.0001	0.191510
SP20	6689	245.05	293	0.92622	0.96644	0.0001	0.190001
Cycle 8							
SP21	0	0	140	0.99201	0.99211	0.0001	0.174008
SP22	0	0	178	0.97788	0.99380	0.0001	0.174805
SP23	480	17.59	229	0.95669	0.98986	0.0001	0.178296

* Note: SP5a was run using 294 degree Kelvin temperatures for U-235 and U-238 rather than 587 degrees Kelvin.

09/26/03

√

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7. Not Used.

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JAH 09/26/03

9. COLD LISTING

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OCRWM	**SPECIAL INSTRUCTION SHEET** ✓file list ok DE 2/24/04	1. QA: QA Page 1 of 1

This is a placeholder page for records that cannot be scanned.

2. Record Date 01/08/04	3. Accession Number ATT-TO: DOC.20040109.0003
4. Author Name(s) J. W. Harwell	5. Authorization Organization Framatome ANP, Inc.

6. Title/Description
Commercial Reactor Reactivity Analysis for Grand Gulf, Unit 1

7. Document Number(s) 32-5029393	8. Version Designator 00
9. Document Type Calculation	10. Medium DVD

11. Access Control Code
PUB ~~N/A~~ TO 2-28-04

12. Traceability Designator
32-5029393, DC#38097

13. Comments
File listing for DVD attachment contained on page 82 and 83.

THIS DOCUMENT
CONTAINS AN
ELECTRONIC ATTACHMENT

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 Volume Serial Number is 4742-E369

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06/17/2003  08:25a      <DIR>          My Pictures
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