Response to Fourth Request for Additional Information—ANP-10278P

"U.S. EPR Realistic Large Break Loss of Coolant Accident Topical Report"

(TAC NO. MD4978)

RAI-35: *Describe the detailed calculation procedure to calculate the core wide and hot assembly stored energy and the fuel pellet conductivity used for this calculation. Provide initial EPR core wide stored energy and hot assembly, both fuel centerline and volume average temperature, as function of fuel burn-up throughout the entire cycle as calculated with S-RELAP5.*

Response to RAI-35:

The stored energy is represented by the fuel rod temperatures computed for the steady-state initial conditions for each realistic large break loss-of-coolant accident (RLBLOCA) case at a specific time in the fuel cycle. The steady state initialization is followed by the transient computation. The process involves:

1. Time in the cycle
2. Axial and radial power distribution
3. RODEX3A fuel state initialization
4. S-RELAP5 input "mod sets"
5. Adjusting the hot rod (UO_2 and Gd) thermal conductivity to account for the increased initial stored energy (initial fuel temperatures) at burnups greater than 10 GWd/MTU.

The entire process is automated to compute the prescribed number of cases that are selected by a statistical process. Each case has its own initialization and transient computation. The methodology is documented in Reference 1. The following discussion is based on Reference 1 and describes the initialization process that leads to the computation of initial fuel temperatures (stored energy).

Treatment of Time-in-Cycle

The RLBLOCA methodology samples time-in-cycle. [ ] performed using an NRC-approved methodology (References 2 and 3).

The time-in-cycle sampling process establishes the fuel rod properties and the lower bound for the global power peaking factor, Fq. In contrast to a traditional safety analysis that assumes conservative fuel rod models consistent with Appendix K requirements, [ ] The method is as follows (from Reference 1, Section 5.1.3.2).

[ ]

The data produced by this method is used primarily to develop input for the RODEX3A code.
[
]

Treatment of Axial and Radial Power Shapes

Axial

The following description of the treatment of axial power shapes is taken from Reference 1, Section 5.1.3.3.

Radial

RODEX3A Fuel State Initialization

RODEX3A is used to compute the initial fuel state at the burnup for the RLBLOCA case being considered. The result is a binary file of fuel rod data that is automatically transferred, without intervention, to the S-RELAP5 steady-state initialization process.

[1] The signs of the terms in parentheses for IP and AA are corrected from those in Reference 1, Page 5-7.

The fuel rod types considered by RODEX3A and S-RELAP5 are:

1. Hot UO_2 rod (201)
2. Hot assembly (202)
3. Hot ring (assemblies surrounding the hot assembly) (203)
4. Average ring (core averaged fuel assembly) (204)
5. Low-powered, outer ring (balance of core assemblies) (205)
6. 2.0% Gd rod (206)
7. 4.0% Gd rod (207)
8. 8.0% Gd rod (208)

The numbers in parentheses are the S-RELAP5 fuel rod heat structure numbers. There is a one-to-one correspondence between the fuel rods modeled in RODEX3A and those in S-RELAP5.

S-RELAP5 contains all RODEX3A functions except for the following (per Reference 6, Page 3-70:

- The cladding thermal property routine was changed to compute properties at the higher temperatures possible in a transient.
- A cladding ballooning and rupture strain model was added to calculate deformations that can occur at elevated cladding temperatures when the internal rod pressure exceeds the coolant channel pressure. The RLBLOCA methodology conservatively neglects swelling and rupture.
- The RODEX3A quasi-steady-state temperature solution algorithm was replaced by the S-RELAP5 transient temperature solution algorithm. The S-RELAP5 algorithm accounts for the thermal capacitance of the fuel.

The S-RELAP5/RODEX3A model does not calculate the burnup response of the fuel. Instead, fuel conditions at the burnup of interest are transferred via a binary data file from RODEX3A to S-RELAP5, establishing the initial state of the fuel prior to the transient.

S-RELAP 5 Steady State Modsets

The steady-state S-RELAP5 input files, built for the RLBLOCA analysis, are generated from a base input file built in compliance with Reference 1. The automation process generates the S-RELAP5 input files. The case-specific input related to stored energy, which is appended to the base input file, includes the following data:

- Axial power profile
- Radial power profile
- Core power
- Initial stored energy (fuel centerline temperature)

Adjust Hot Rods Stored Energy

The initial stored energy of the rods, in terms of initial transient conditions, is adjusted upward to account for the over-predicted fuel pellet thermal conductivity in RODEX3A for burnups greater than 10 MWd/kgU. The fuel centerline temperature correction is presented in Reference 1, Page 4-93.

Fuel Pellet Thermal Conductivity

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U.S. EPR Initial Stored Energy

For completeness, Appendix A is the response to U.S. EPR design certification RAI-167, Question 38. It presents the core-wide stored energy as a function of fuel burnup at five times in the cycle for the highest PCT case, Case 44, in the RLBLOCA analysis of Reference 7.

References:

1. EMF-2103(P)(A) Revision 0, “Realistic Large Break LOCA Methodology for Pressurized Water Reactors,” AREVA NP Inc., April 2003.
2. XN-75-27(A), "Exxon Nuclear Neutronic Design Methods for Pressurized Water Reactors," Exxon Nuclear Company, April 1977.
3. EMF-96-029(P)(A), “Reactor Analysis System for PWRs,” AREVA NP Inc., January 1997.

4. EMF-2062(P), G104,075, Revision 1, “Guidelines for PWR Safety Analysis, S-RELAP5 Realistic Large Break LOCA Analysis,” AREVA NP Inc., June 2005.
5. EMF-2054(P), Revision 2, “Code Input Development Guidelines for Realistic Large Break LOCA Analysis of a Pressurized Water Reactor,” AREVA NP Inc., July 2001.
6. EMF-2101(P), Revision 3, “S-RELAP5 Programmers Guide,” AREVA NP Inc., May 2004.
7. ANP-10278P, Revision 0, “U.S. EPR Realistic Large Break Loss of Coolant Accident Topical Report,” AREVA NP Inc., March 2007.
8. EMF-1557P, Revision 8, “RODEX3A: Theory and Users Manual,” AREVA NP Inc., May 2007.
9. EMF-2062(P), G104,074, Revision 2, “Code Input Development Guidelines for Realistic Large Break LOCA Analysis of a Pressurized Water Reactor,” AREVA NP Inc., May 2005.

RAI 36: It was noted that the average assembly initial stored energy was not readjusted using the correlation documented on Page 4-93 of Reference 1. It appears that the initial stored energy for the average core assembly was underestimated. Provide the analysis to quantify the underestimated stored energy and evaluate the impact on the PCT.

Reference 1 - EMF-2103 revision 0, “Realistic Large break LOCA for Pressurized Water Reactors.” August 2001.

Response to RAI-36:

To quantify the relative stored energy for the average assembly and the impact on peak cladding temperature (PCT), additional computations were performed for Case 44. Case 44 is the maximum PCT case from the 59-case equilibrium cycle uncertainty analysis reported in Reference 1. The case is inlet-peaked, with PCT occurring early in the transient.

Two sensitivity studies were performed to determine the impact of increasing the core-average, and the core-wide stored energy. Both studies apply the burnup adjustment for stored energy described on Page 4-93 of Reference 2 to all regions of the core, not just to the hot rods (Reference 2 only applies the burnup adjustment to the hot rods).

1. The first sensitivity study builds upon the calculation reported in the response to RAI-35, ANP-10278Q5. The calculations include a range of burnups for the hot rod, hot assembly, central core, average core, and outer core.

   The first step is to select appropriate burnups for the core regions. The 18 month, equilibrium cycle has a core average exposure at beginning of cycle (BOC) and end of cycle (EOC) of 18.296 GWd/MTU and 37.474 GWd/MTU, respectively. These burnups correspond to a time step of approximately 29 for 18.296 GWd/MTU and greater than 40 for 37.474 GWd/MTU.

   This assessment assumes that the average core burnup is 19.8 GWd/MTU, which corresponds to a time step of 31. The outer core is assumed to have a burnup of 25.6 GWd/MTU, which corresponds to a time step of 40. These assumptions allow the use of the calculations described in RAI-35.

2. A second sensitivity study examines the effect on PCT of applying the hot rod FUELK multiplier for Case 44 hot rods to all regions of the core, without regard to the spatial variations in burnup. This approach increases the stored energy in all core regions, as was done in the hot rods.

The following tables quantify an underestimation of initial stored energy for the two studies identified above. In each study, the stored energy is presented as the fuel centerline temperature and core average temperature at steady state for each of the eight core regions. The table also presents the PCT results. The change in PCT from the base case is less than 50°F for both sensitivity cases.

The value of the FUELK multiplier is presented in Table 36-1. Comparing the sensitivity study runs to the base cases, the value of the FUELK multiplier is lower in the following regions: hot assembly, "surrounding" assembly, "average" assembly, and “cold outer” assembly. Therefore, the temperatures calculated in the sensitivity studies for these regions are expected to be higher

than their base-case counterparts. The value of 1.0 for FUELK in these four regions is not explicitly defined in the S-RELAP5 input.

Table 36-2 shows a summary of the maximum fuel rod temperatures at the pellet centerline (inner radius) for all core regions. As expected, the hot assembly and "surrounding" assembly temperatures increase in the sensitivity studies as a result of a smaller fuel thermal conductivity. The temperatures of the average assembly and outer assembly in the sensitivity studies are also greater than in the base case. The configuration of the second sensitivity study, with fresh fuel in the average and core outer regions, produces higher temperatures in the average and core outer assemblies. However, the highest axial maximum and axial average temperatures, which are in the hot UO_2 rod, are unchanged from the base, bin 1 case. The fuel volume average temperatures in Table 36-3 show similar behavior.

The computations show that the underestimation of initial stored energy in the average core region and the outer core region has a negligible effect on the PCT calculation. Therefore, the readjustment of the initial stored energy will continue to be performed for only the hot rods: UO_2 and gadolinium (Gd).

PCTs for the eight rod types (from the RODEX3A edit in the S-RELAP5 OUTPUT) are summarized in Table 36-4. There are minor differences in PCT time and in PCT node location, but there are no significant PCT differences for the three cases.

The computations show that the underestimation of initial stored energy in the average core region and the outer core region has a negligible effect on the PCT calculation. Therefore, the readjustment of the initial stored energy will continue to be performed for only the hot rods: UO_2 and Gd.

References:

1. ANP-10278P, Revision 0, “U.S. EPR Realistic Large Break Loss of Coolant Accident Topical Report,” AREVA NP Inc., March 2007.
2. *EMF-2103(P)(A), Revision 0, “Realistic Large break LOCA for Pressurized Water Reactors,” August 2001.*

Table 36-1: Sensitivity Study Results – FUELK Multiplier

Region	FUELK				
	Base Case Time-in-Cycle (hrs)			Sensitivity	
	101 (bin 1)	10131 (bin 31)	13137 (bin 40)	1	2
Hot UO_2 Rod	0.95419	0.924836	0.930678	0.95419	0.95419
Hot Assembly	1.0	1.0	1.0	0.95419	0.95419
Surrounding Assembly	1.0	1.0	1.0	0.95419	0.95419
2% Gd Rod	0.95419	0.924836	0.930678	0.95419	0.95419
4% Gd Rod	0.95419	0.924836	0.930678	0.95419	0.95419
8% Gd Rod	0.95419	0.924836	0.930678	0.95419	0.95419
Average Assembly	1.0	1.0	1.0	0.893266	0.95419
Cold Outer Assembly	1.0	1.0	1.0	0.749639	0.95419

Table 36-2: Sensitivity Study Results - Maximum Fuel Rod Temperature Summary

Sensitivity	Region	Burn Time (hrs)					
		101 (bin 1)		10131 (bin 31)		13137 (bin 40)	
		Axial Max (°F)	Axial Avg (°F)	Axial Max (°F)	Axial Avg (°F)	Axial Max (°F)	Axial Avg (°F)
Base (From RAI-167, Question 38)	Hot UO_2 Rod	3323	2423	3026	2202	2990	2136
	Hot Assembly	2815	2087	2675	1969	2667	1888
	Surrounding Assembly	2289	1730	2156	1638	2116	1586
	2% Gd Rod	2090	1615	3168	2316	3117	2240
	4% Gd Rod	2014	1571	3301	2438	3189	2329
	8% Gd Rod	1786	1428	3263	2459	3094	2348
	Average Assembly	2198	1666	2069	1578	2031	1529
	Cold Outer Assembly	1277	1044	1218	1007	1200	986
1	Hot UO_2 Rod	3323	2423				
	Hot Assembly	2912	2151				
	Surrounding Assembly	2362	1779				
	2% Gd Rod	2090	1615				
	4% Gd Rod	2014	1571				
	8% Gd Rod	1786	1428				
	Average Assembly			2255	1687		
	Cold Outer Assembly					1399	1107
2	Hot UO_2 Rod	3323	2423				
	Hot Assembly	2912	2151				
	Surrounding Assembly	2362	1779				
	2% Gd Rod	2090	1615				
	4% Gd Rod	2014	1571				
	8% Gd Rod	1786	1428				
	Average Assembly	2267	1713				
	Cold Outer Assembly	1309	1065				

Table 36-3: Sensitivity Study Results – Volume Averaged Fuel Rod Temperature Summary

Sensitivity	Region	Burn Time (hrs)					
		101 (bin 1)		10131 (bin 31)		13137 (bin 40)	
		Axial Max (°F)	Axial Avg (°F)	Axial Max (°F)	Axial Avg (°F)	Axial Max (°F)	Axial Avg (°F)
Base (From RAI-167, Question 38)	Hot UO_2 Rod	2052	1591	1877	1458	1839	1419
	Hot Assembly	1798	1419	1709	1353	1700	1301
	Surrounding Assembly	1513	1223	1442	1177	1417	1150
	2% Gd Rod	1405	1162	1948	1525	1916	1478
	4% Gd Rod	1362	1136	2023	1591	1950	1524
	8% Gd Rod	1236	1056	2038	1620	1925	1554
	Average Assembly	1463	1188	1395	1144	1371	1119
	Cold Outer Assembly	965	845	937	827	926	817
1	Hot UO_2 Rod	2052	1591				
	Hot Assembly	1843	1449				
	Surrounding Assembly	1548	1246				
	2% Gd Rod	1405	1162				
	4% Gd Rod	1362	1136				
	8% Gd Rod	1236	1056				
	Average Assembly			1481	1195		
	Cold Outer Assembly					1018	874
2	Hot UO_2 Rod	2052	1591				
	Hot Assembly	1843	1449				
	Surrounding Assembly	1548	1246				
	2% Gd Rod	1405	1162				
	4% Gd Rod	1362	1136				
	8% Gd Rod	1236	1056				
	Average Assembly	1496	1210				
	Cold Outer Assembly	980	855				

Table 36-4: Sensitivity Study Results – Peak Cladding Temperature for Each Region

Region	Base (From analyses supporting RAI-167, Question 38, bin 1)			Sensitivity					
				1			2		
	PCT (°F)	PCT Node	Time (s)	PCT (°F)	PCT Node	Time (s)	PCT (°F)	PCT Node	Time (s)
Hot UO_2 Rod	1466	10	33.9	1485	10	41.4	1475	15	46.5
Hot Assembly	1248	10	33.6	1275	10	33.9	1271	10	33.7
Surrounding Assembly	1061	10	33.6	1072	10	33.9	1080	10	33.8
2% Gd Rod	1144	10	35.8	1161	10	33.9	1151	15	46.5
4% Gd Rod	1109	10	35.8	1127	10	34	1117	10	33.8
8% Gd Rod	1033	11	33.6	1051	11	34	1041	11	33.8
Average Assembly	995	10	33.6	982	5	33.2	1006	10	33.7
Cold Outer Assembly	652	47	0	652	47	0	652	47	0

RAI 37: *During the audit on December 3, 2008, AREVA stated that "historically, power impact of burnup results in lower PCTs for second and third cycle fuel." Therefore, there would be no need to correct the initial stored energy for the hot rod beyond the first cycle with a burn-up limit of 30 GWD/MTU. This implicitly restricts the current LBLOCA methodology and the future core design to have hot rod during the first cycle fuel. Discuss the process AREVA will implement for future fuel designs to verify the assumption that second and third cycle fuel are not limiting in terms of fuel stored energy and PCT.*

Response to RAI-37:

Within the U.S. EPR's current fuel cycle design guidelines, a reload check is performed to confirm that the maximum local heating rate within the core, under normal operating conditions, occurs in fresh fuel throughout the entire cycle. Specifically, a check is made to confirm that the maximum radial power peaking ($F_{\Delta H}$) and the nodal power peaking (F_Q or linear heat rate) occur in a fresh fuel assembly throughout the cycle. Because third cycle fuel is strongly depleted and cannot approach the peaking of first or second cycle fuel, this check essentially verifies that loss-of-coolant accident (LOCA) calculations for first cycle fuel will bound, or at a minimum approximate, any calculations for second and third cycle fuel.

To assure that the peak cladding temperature (PCT) will occur in fresh fuel, an accounting of the increase in fuel average enthalpy with burnup is made. To do this, AREVA NP will revise the U.S. EPR reload check to compare the cycle design peak operating fuel enthalpy of fresh fuel to that of once burned fuel, and to confirm that, at any time in the cycle, the operating enthalpy of fresh fuel is greater than that of once-burned fuel. Because of fuel pellet thermal conductivity degradation during the second cycle of operation, this condition requires that the maximum linear heating rate for second cycle fuel be less than that for fresh fuel. In combination, this means that the total energy that must be transported through the cladding up to the time of PCT for second cycle fuel is less than that of fresh fuel, and that the PCT will occur in the fresh fuel. Should the fuel enthalpy of second cycle fuel exceed that of fresh fuel at any point in the cycle, the conditions will be examined for the possibility that the highest PCT of the realistic large break LOCA (RLBLOCA) case set could occur in second cycle fuel. If that possibility cannot be ruled out, either:

1. The cycle design will be altered to preclude a second cycle PCT, or

2. The RLBLOCA calculation will be expanded to include second cycle fuel.

With this approach, for burnup effects on the initial fuel conditions, the criteria of 10 CFR 50.46 are met with high probability.

Appendix A – Request for Additional Information No. 167, Supplement 1
Response to Question 38

Question 15.06.05-38:

Provide hot rod center line and volume average fuel temperature predictions as a function of burnup (both core average and hot rod burnup) for EPR fuel as predicted by RODEX3A/S-RELAP5 for RLBLOCA.

Response to Question 15.06.05-38:

The fuel rod temperatures were calculated at five times in the cycle for the limiting peak cladding temperature (PCT) case (i.e., Case 44) in the realistic large break loss of coolant accident (RLBLOCA) analysis of Topical Report ANP-10278P (Reference 1). The computational process is identical to the reference Case 44 computation except for the selected times in the cycle.

The RLBLOCA core modeling included in RODEX3A and S-RELAP5 for Case 44 consists of eight fuel rod types:

1. Hot UO_2 rod.
2. Hot assembly.
3. Hot ring (assemblies surrounding the hot assembly).
4. Average ring (core averaged fuel assembly).
5. Low-powered, outer ring (balance of core assemblies).
6. 2.0 percent Gadolinia (Gd) rod.
7. 4.0 percent Gd rod.
8. 8.0 percent Gd rod.

Rod types 1, 6, 7, and 8 are potential PCT rods (hot rods). The remaining rod types model the balance of the core and drive the thermal-hydraulic response of the system. The hot rods get their boundary conditions from the hot assembly.

Calculations of the fuel centerline (pellet inner radius) and volume average temperature are presented in the following tables and figures for the eight fuel rod types.

Table 15.06.05-38-1 presents the fuel rod average burnups for the eight fuel rod types at the five times in cycle. Table 15.06.05-38-1 is provided to explain the rod average burnups in the tabular data for maximum and volume average fuel (pellet) temperatures.

Table 15.06.05-38-2 and Table 15.06.05-38-3 present the maximum fuel centerline (inner radius) temperatures for the eight fuel rod types modeled in the RODEX3A/RELAP5 computations for Case 44. Figure 15.06.05-38-1 through Figure 15.06.05-38-8 show the axial distribution of fuel centerline (inner radius) temperatures. Table 15.06.05-38-4 and Table 15.06.05-38-5 present the volume average temperature for the eight fuel rod types modeled in the RODEX3A/RELAP5 computations for Case 44. Figure 15.06.05-38-9 through Figure 15.06.05-38-16 show the axial distribution of volume average fuel temperatures. These tables and figures show that the temperature variation is moderately affected by burnup and the trend is a decrease in temperatures with burnup.

Extending the steady state computation to the transient computation provides the PCT for each of the times in cycle. Table 15.06.05-38-6 shows the maximum cladding temperatures for the eight fuel rod types at the five times in cycle. The maximum cladding temperature of the eight fuel rod types for each burn up is shown in the bottom row. The largest difference of the maximum temperatures is approximately 81°F.

The PCT at the burnup of Case 44 (analysis of record) is 1425°F and the maximum cladding temperature rod for this case is the 4 percent Gd rod (see Table 15.06.05-38-6).

Figure 15.06.05-38-17 presents the data from Table 15.06.05-38-6 as a graph. The maximum cladding temperatures of the UO_2 fuel rods are moderately affected by the time in cycle and with a downward trend with increasing time in cycle. Gd bearing rods have lower initial stored energy at low burnup as compared to the UO_2 hot rod. As the Gd burns out, the maximum cladding behavior is similar to the hot UO_2 rod. The maximum cladding temperatures are moderately dependent on time in cycle (burnup) with a general downward trend, which is consistent with the initial steady state fuel rod temperatures.

In addition to the requested information, the RODEX3A/S-RELAP5 computations provide the steady state gap conductance and rod internal pressure for RLBLOCA Case 44 at five times in cycle and for the eight fuel rod types. Table 15.06.05-38-7 presents the rod internal pressure at five times in the cycle for the eight fuel rod types. The fuel rod gap conductance varies along the axial length. Table 15.06.05-38-8 and Table 15.06.05-38-9 show the axial maximum and axial average gap conductance at five times in the cycle. Figure 15.06.05-38-18 through Figure 15.06.05-38-25 present the axial distribution of gap conductance at five times in the cycle for the eight fuel rod types.

Figure 15.06.05-38-18, Figure 15.06.05-38-19, and Figure 15.06.05-38-20 show a progression of gap conductance for the hot rod, hot assembly, and surrounding assemblies as a function of burnup. With the exception of the highest burnup case, the gap conductance trend is the same for the hot rod, hot assembly, and surrounding assemblies. The hot assembly gap conductance behavior illustrated in the highest burnup case in Figure 15.06.05-38-19 is different from the surrounding assemblies and hot rod because the hot assembly is at an intermediate stage of burnup and gap closure. For this burnup, the hot rod has a closed gap over a significant part of its axial length; thus, it has a high gap conductance that is uniform over most of the axial length as shown in Figure 15.06.05-38-18. The closed gap of the hot rod is due to higher fast fluence and burnup than for the hot assembly rod. The rods of the surrounding assemblies have an open gap at the highest burnup and a lower gap conductance behavior that is uniform over its axial length as shown in Figure 15.06.05-38-20. The highest burnup hot assembly rod has a nonuniform gap conductance because it has a mix of closed, open, and partially closed gaps along its axial length as shown in Figure 15.06.05-38-19. The illustrated behavior is consistent with the modeling in RODEX3A, and the fuel rod data show the expected behavior for the various fuel types.

References for Question 15.06.05-38:

1. AREVA NP Topical Report ANP-10278P, Revision 0, “U.S. EPR Realistic Large Break Loss of Coolant Accident,” AREVA NP Inc., March 2007.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Table 15.06.05-38-1—Rod Average Burnups, Five Times in Cycle

Time in Cycle (hours)	101	3039	6416	10131	13137
	Fuel Rod Average Burnups, GWd/MTU				
Hot UO2 Rod	0.22	6.71	14.25	22.50	28.90
Hot Assembly	0.20	6.00	12.86	20.49	26.56
Surrounding Assemblies	0.15	4.63	9.77	15.42	19.99
Core Average Assemblies	0.15	4.63	9.77	15.42	19.99
Outer Core Assemblies	0.15	4.63	9.77	15.42	19.99
2% Gd Rod	0.11	4.59	11.68	19.36	24.12
4% Gd Rod	0.10	3.81	10.17	17.85	23.93
8% Gd Rod	0.08	2.88	7.47	14.92	21.00

Table 15.06.05-38-2—Maximum Fuel Rod Temperatures in Assemblies, Five Times in Cycle

Table 15.06.05-38-3—Maximum Hot Fuel Rod Temperatures, Five Times in Cycle

Table 15.06.05-38-4—Volume Average Fuel Rod Temperatures in Assemblies, Five Times in Cycle

Table 15.06.05-38-5—Volume Average Hot Fuel Rod Temperatures, Five Times in Cycle

Table15.06.05-38-6—Maximum Cladding Temperatures, Five Times in Cycle

Table 15.06.05-38-7—Fuel Rod Internal Gas Pressure, Five Times in Cycle

Table 15.06.05-38-8—Fuel Rod Gap Conductance in Assemblies, Five Times in Cycle

Table 15.06.05-38-9—Hot Fuel Rod Gap Conductance, Five Times in Cycle

Figure 15.06.05-38-1—Maximum Temperature, Hot UO_2 Rod, Five Burnups

Figure 15.06.05-38-2—Maximum Temperature, Hot Assembly UO_2 Rod, Five Burnups

Figure 15.06.05-38-3—Maximum Temperature, Surrounding Assemblies UO_2 Rod, Five Burnups

Figure 15.06.05-38-4—Maximum Temperature, Core Average Assemblies UO_2 Rod, Five Burnups

Figure 15.06.05-38-5—Maximum Temperature, Outer Core Assemblies UO_2 Rod, Five Burnups

Figure15.06.05-38-6—Maximum Temperature, 2% Gd Rod, Five Burnups

Figure 15.06.05-38-7—Maximum Temperature, 4% Gd Rod, Five Burnups

Figure 15.06.05-38-8—Maximum Temperature, 8% Gd Rod, Five Burnups

Figure 15.06.05-38-9—Volume Average Temperature, Hot UO_2 Rod, Five Burnups

Figure 15.06.05-38-10—Volume Average Temperature, Hot Assembly UO_2 Rod, Five Burnups

Figure 15.06.05-38-11—Volume Average Temperature, Surrounding Assemblies UO_2 Rod, Five Burnups

Figure 15.06.05-38-12—Volume Average Temperature, Core Average Assemblies UO_2 Rod, Five Burnups

Figure 15.06.05-38-13—Volume Average Temperature, Outer Core Assemblies UO_2 Rod, Five Burnups

Figure 15.06.05-38-14—Volume Average Temperature, 2% Gd Rod, Five Burnups

Figure 15.06.05-38-15—Volume Average Temperature, 4% Gd Rod, Five Burnups

Figure 15.06.05-38-16—Volume Average Temperature, 8% Gd Rod, Five Burnups

Figure 15.06.05-38-17—Maximum Cladding Temperatures, Five Times in Cycle

Figure 15.06.05-38-18—Gap Conductance, Hot UO2 Rod, Five Burnups

Figure 15.06.05-38-19—Gap Conductance, Hot Assembly UO_2 Rod, Five Burnups

Figure 15.06.05-38-20—Gap Conductance, Surrounding Assemblies UO_2 Rod, Five Burnups

Figure 15.06.05-38-21—Gap Conductance, Core Average Assemblies UO2 Rod, Five Burnups

Figure 15.06.05-38-22—Gap Conductance, Outer Core Assemblies UO_2 Rod, Five Burnups

Figure 15.06.05-38-23—Gap Conductance, 2% Gd Rod, Five Burnups

Figure 15.06.05-38-24—Gap Conductance, 4% Gd Rod, Five Burnups

Figure 15.06.05-38-25—Gap Conductance, 8% Gd Rod, Five Burnups