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Power Histories for Fuel Codes

Prepared by E. R. Gilbert, W. N. Rausch, F. E. Panisko

Pacific Northwest Laboratory
Operated by
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ABSTRACT

Computations of power history effects on the pre-loss-of-coolant accident (LOCA) conditions of generic pressurized water reactor (PWR) and boiling water reactor (BWR) fuel rods were performed at Pacific Northwest Laboratory using the U.S. Nuclear Regulatory Commission (NRC) code FRAPCON-2. Comparisons were made between cases where the fuel operated at a high ("LOCA-limited") power throughout life (20,000 MWd/MTU) and those where the fuel was at a lower power for most of its burnup and ramped to the high power at 10,000 or 20,000 MWd/MTU burnup.

The PWR rod was calculated to have more cladding creepdown during the lower power cases, which resulted in slightly lower centerline temperatures (as much as 100°C). This result was insensitive to the method used to increase the power during the ramps (i.e., by increasing the average rod power or by changing the peak-to-average (P/A) ratio of the axial power shape). The calculations also indicate that the highest fuel centerline temperatures were reached at startup.

The BWR rod, however, demonstrated a substantial dependence on the power history. In this case, the constant high-power rod released considerably more fission gas than the lower power cases (21% versus 0.4%), which resulted in temperature differences of up to 350°C. The highest temperature was reached at end-of-life (EOL) in the constant high-power case.

SUMMARY

The objective of this Pacific Northwest Laboratory (PNL) program was to assess the impact of some power history assumptions on end-of-life (EOL) fuel temperature calculations and recommend appropriate assumptions for safety analysis.

Two generic fuel rods were simulated with the U.S. Nuclear Regulatory Commission (NRC) audit code FRAPCON-2 to determine the effects of power history assumptions on pre-LOCA fuel temperatures. The fuel rods chosen for the study correspond to a commercial pressurized water reactor (PWR) (15 x 15) design and a commercial boiling water reactor (BWR) (8 x 8) design. The base case calculation for each rod was performed by extending the computer code to 20,000 MWd/MTU at the "loss-of-coolant accident (LOCA)-limited" linear heat generation rate (LHGR).[a] Computer runs were made to simulate the behavior of each fuel rod at 0.5 and 0.7 times the peak power. At various burnups, the code then modeled ramps to the LOCA-limited LHGR (12.6 kW/ft and 13.4 kW/ft were chosen as typical values for the PWR and BWR rods, respectively). The PWR rods were ramped in two ways: by increasing the average power or by modifying the peak-to-average (P/A) ratio. The BWR rods were ramped by raising the average power to the LOCA-limited peak.

The PWR calculations gave very similar results regardless of the power history or method of ramping. The final temperature of the constant high-power case was higher than for the rods run at low powers and then ramped. This difference was less than 100°C and apparently resulted from increased cladding creepdown that was calculated to occur early in the life of the low-power rods. The lower power rod experienced more creepdown than the higher power rod because fuel thermal expansion was less; thus, more cladding creepdown was allowed before the fuel supported the cladding.

(a) The highest power licensable due to considerations of potential cladding temperatures during a postulated LOCA.

The BWR rod showed a definite power history effect. The most significant disparity between the high- and low-power cases occurred in the fission gas release fraction (21% versus 0.4%). Temperatures calculated in the low-power case ranged from 150°C at 10,000 MWd/MTU to 350°C at 20,000 MWd/MTU less than the temperatures calculated for the constant high-power case.

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INTRODUCTION

Steady-state fuel performance codes like FRAPCON-2,[1] a U.S. Nuclear Regulatory Commission (NRC) audit code, have their major impact on loss-of-coolant accident (LOCA) analysis. Fuel rod temperatures, which are calculated as the starting point for the emergency core cooling system (ECCS) analysis, have a dominant effect on LOCA peak cladding temperature and are subject to large variations due to power history effects. The power history assumptions vary from vendor to vendor; therefore, there is a need to review some of the vendor assumptions to confirm their adequacy.

In reviewing safety analyses as part of the licensing of nuclear power plants, the NRC performs calculations of fuel parameters and response using fuel performance computer codes. The predictions of these codes are dependent on not only the conditions at the time of a hypothetical accident but also the conditions prior to the event. The purpose of this Pacific Northwest Laboratory (PNL)[a] program was to provide assistance in determining power history effects in fuel performance codes used for plant safety analyses.

Generic pressurized water reactor (PWR) and boiling water reactor (BWR) fuel rods were simulated using FRAPCON-2 to determine the effects of certain power history assumptions on pre-LOCA fuel temperatures. The base case calculation for each rod was performed by extending the computer code to 20,000 MWd/MTU at the LOCA-limited linear heat generation rate (LHGR). Computer runs simulated the behavior of each fuel rod at 0.5 and 0.7 times the peak power. At various burnups, the calculations then modeled ramps to the LOCA-limited LHGR.

The remainder of this report consists of the conclusions that were reached and a presentation of the approach that was used, the results that were obtained, and a discussion of those results. The appendix contains power history data and code output for the generic PWR and BWR rods.

(a) Operated for the U.S. Department of Energy (DOE) by Battelle Memorial Institute.

CONCLUSIONS

The results calculated by FRAPCON-2 showed that the specific choices of power history had very little effect on the EOL centerline temperatures for the PWR cases. In all PWR cases, the fuel rod was predicted to reach its highest temperature at beginning of life (BOL). The method of ramping the fuel rod--changing the peak-to-average (P/A) ratio or increasing the average power--did not influence the results.

The BWR cases, however, demonstrated a significant dependence upon power history. The constant high-power rod released considerably more fission gas than the lower power cases; this resulted in EOL temperatures that were as much as 350°C higher for the constant high-power case.

It appears that in the case of PWR fuel the method of modeling fuel performance by operating the fuel at typical commercial powers (6 to 9 kW/ft) and then ramping to the peak licensable LHGR may be a suitable substitute for calculating fuel thermal performance by modeling a constant high-power history. For the BWR, however, the constant high-power history case was more conservative at higher burnup conditions than the low-power/ramp technique. Although this does not necessarily invalidate the low-power method, it does indicate that more work would be necessary to assess which power history is more realistic with respect to licensing for modeling commercial fuel performance.

ANALYSIS OF POWER HISTORY EFFECTS

This section includes a description of the approach that was used in the analysis, a presentation of the results, and a discussion of those results.

APPROACH

Representative power histories consisted of operation at a fixed power level followed by an instantaneous increase to a LOCA-limited peak power at which critical output parameters (e.g., volume average fuel temperature, rod internal pressure) were calculated. The calculational matrix included two fuel designs--a PWR 15 x 15 and a BWR 8 x 8 design[a]--three steady-state power levels--0.5, 0.7, and 1.0 times the fuel rod LOCA-limited peak power level. The power was increased by changing the rod average power while maintaining a constant P/A power ratio for both PWR and BWR cases. An additional set of cases was produced by changing the axial power distribution for some special PWR cases.

The specific cases used to assess the impact of power history assumptions on LOCA-limited fuel temperature cladding calculations were as follows: The power history effects on pre-LOCA conditions were computed for a generic 15 x 15 PWR fuel rod with a peak LHGR of 12.6 kW/ft[b] and a steady-state pre-LOCA LHGR of 8.8 kW/ft (0.7 times the peak LHGR) and 6.3 kW/ft (0.5 times the peak LHGR) for burnups of 26 MWd/MTU (i.e., BOL), 10,000 MWd/MTU, and 20,000 MWd/MTU using the FRAPCON-2 code with FRACAS-2 mechanical model and the ANS 5.4 fission gas release model. A special case was conducted with a steady-state pre-LOCA LHGR of 8.8 kW/ft for a burnup of 2000 MWd/MTU. In all cases, the power was ramped to 12.6 kW/ft at the specified burnup. The computer outputs are tabulated in Appendix A.

Similar computations were conducted for a generic 8 x 8 BWR fuel rod with a peak LHGR of 13.4 kW/ft[b] and a steady-state pre-LOCA LHGR of 9.4 kW/ft (0.7 times the peak LHGR) and 6.7 kW/ft (0.5 times the peak LHGR) for burnups of BOL, 10,000 MWd/MTU, and 20,000 MWd/MTU.

(a) See Reference 2 for physical descriptions of the fuel rods.
(b) Peak power values were chosen to represent typical PWR and BWR LOCA-limited LHGRs.

Computations were made for conditions of constant P/A power ratios of 1.2 (PWR) and 1.3 (BWR). The power was increased at the specified burnup by increasing the rod power and maintaining the same P/A power ratios. An alternate method of power ramping to LOCA conditions--maintaining a constant rod average power but altering the axial power distribution to enable attainment of the LOCA conditions in a segment of the rod--was performed for PWR burnups at BOL, 10,000 MWd/MTU, and 20,000 MWd/MTU with pre-LOCA power of 8.8 kW/ft (0.7 times the peak LHGR). The power histories for these cases are also described in the appendix.

The FRAPCON-2 code, which is described in Reference 1, is a steady-state model developed jointly by EG&G Idaho[(a)] and PNL for the Fuel Behavior Research Branch of the NRC. The FRACAS-2 mechanical subcode was selected to compute the fuel-cladding interactions, while fission gas release was computed with the ANS 5.4 option. FRACAS-2 uses the effective fuel conductivity and the relocated fuel-cladding gap size for thermal calculations. The relocated fuel surface is used in the mechanics calculations. A model is included for time-dependent hot pressing of misaligned fuel fragments. The FRAPCON-2 code includes cladding creepdown under the external pressure of the coolant. Code verification is presented in References 3 and 4. The selection of code options as described in Reference 1 for these computations is presented in Table 1.

(a) Idaho National Engineering Laboratory is operated for DOE by EG&G Idaho, Inc.

TABLE 1. Computer Code Input

```
WESTINGHOUSE 15 X 15
 $FRPCN
 IM = 33, MECHAN = 1, NA = 10, NC = 4, NF = 5, NR = 11, NGASR = 6,
 MECHAN = 3,
 $END
 $FRPCUN
 CPL = 0.21, DCI = .00948, DCO = .010714, DP = .00929, DELTAZ = 10*0.366,0.21,
 DEN = 95.0, DISHSD = 0.001, HDISH = 0.001, ENRCH = 2.8, FA = 1.2,
 FGPAV = 3.04E6, FLUX = 6.0E17, HPLT = 0.01524, ICM = 4, IDXGAS = 1,
 IPLANT = 1, IQ = 1, NUNITS = 0, P2 = 15.5E6, TOTL = 3.66, TW = 547.3,
 HSNTR = 109.7,
 BMPY = 0.01,3,6,9,12,15,18,21,24,27,30,33,36,39,41.34,18*41.34,
 TIME = 0.01,0.1,.15,.2,.25,.3,.35,.4,.45,.5,.55,.6,.7,.8,.9,2,.5,.10,,
 30,.50,70,90,110,130,150,170,190,210,230,250,270,290,300,
 JDLPR = 1,
 $END



TITLE, GE 6.7 TO 1 DAY
GENERAL ELECTRIC 8 X 8
 $FRPCN
 IM = 38, MECHAN = 3, NA = 10, NC = 4, NF = 5, NR = 11, NGASR = 6,
 IM = 18,
 $END
 $FRPCUN
 CPL = 0.36, DCI = 0.0108, DCO = 0.012528, DP = 0.01057, DELTAZ = 10*0.371,0.36,
 DEN = 95, DISHSD = .001, HDISH = .001, ENRCH = 1.8, FA = 1.3,
 FGPAV = 1.01E5, FLUX = 6E17, HPLT = 0.01067, ICM = 2, IDXGAS = 1,
 IPLANT = 2, IQ = 1, NUNITS = 0, P2 = 7.14E6, TOTL = 3.71, TW = 551.3,
 HSNTR = 109.7,
 BMPY = 0.01,3,6,9,12,15,18,21,22,22,
 24,27,30,33,36,39,42,43,96,
 TIME = 0.01,0.1,.15,.2,.25,.3,.35,.4,.45,1.,
 1.03,1.06,1.09,1.12,1.15,1.18,1.21,1.24,
 $END
```

RESULTS

The results of the base test matrix for both PWR and BWR generic cases are listed in the Appendix (Tables A.1 through A.15) for constant P/A power ratios, and the results for the 15 x 15 PWR cases are plotted in Figure 1. The power ramps executed at BOL from the 0.5 pre-LOCA power level ended precisely on the 1.0 power level curve and passed through the 0.7 level curve during the ramp. The 0.7 case also ended precisely on the 1.0 level curve.

At 2000 MWd/MTU, the 0.7 case fell short of reaching the 1.0 level curve by approximately 25°C. At 10,000 MWd/MTU, the 0.5 case fell short of reaching the 0.7 level curve during the transient by approximately 15°C and fell short of reaching the 1.0 level curve at the end of the transient by approximately 100°C. The 0.7 case fell short of reaching the 1.0 case by approximately 45°C. At 20,000 MWd/MTU, the 0.5 case fell short of reaching the 0.7 level curve during the transient by approximately 10°C and fell short of reaching the 1.0 level curve at the end of the transient by approximately 95°C. The 0.7 case fell short of reaching the 1.0 level curve at the end of the transient by approximately 50°C. The fuel centerline temperatures in Figure 1 were predicted to decrease by 100 to 150°C within the first 10,000 MWd/MTU and then to stabilize during the second half of the computational period (to 20,000 MWd/MTU).

The results for the 8 x 8 BWR cases are plotted in Figure 2. The 0.5 case at BOL passed through the 0.7 curve during the ramp to the 1.0 level curve with which it agreed precisely. The 0.7 case agreed precisely with the 1.0 curve after being ramped at BOL. At 10,000 MWd/MTU, the 0.5 case fell short of the 0.7 curve by 50°C as it was being ramped to the 1.0 curve where it fell short by 190°C. The ramped 0.7 case fell short of the 1.0 curve by 100°C. At 20,000 MWd/MTU, the 0.5 case fell 60°C short of the 0.7 curve as it was being ramped to the 1.0 level where it fell short by 390°C. The 0.7 case fell short by 280°C of the 1.0 curve at the end of its ramp. The fuel centerline temperatures in Figure 2 were predicted to decrease by 100 to 140°C within the first 10,000 MWd/MTU and then to stabilize during the second half of the computational period, except for the steady-state case, at 13.4 kW/ft. In this case the centerline temperature increased by 200°C during the second half of the computational period.

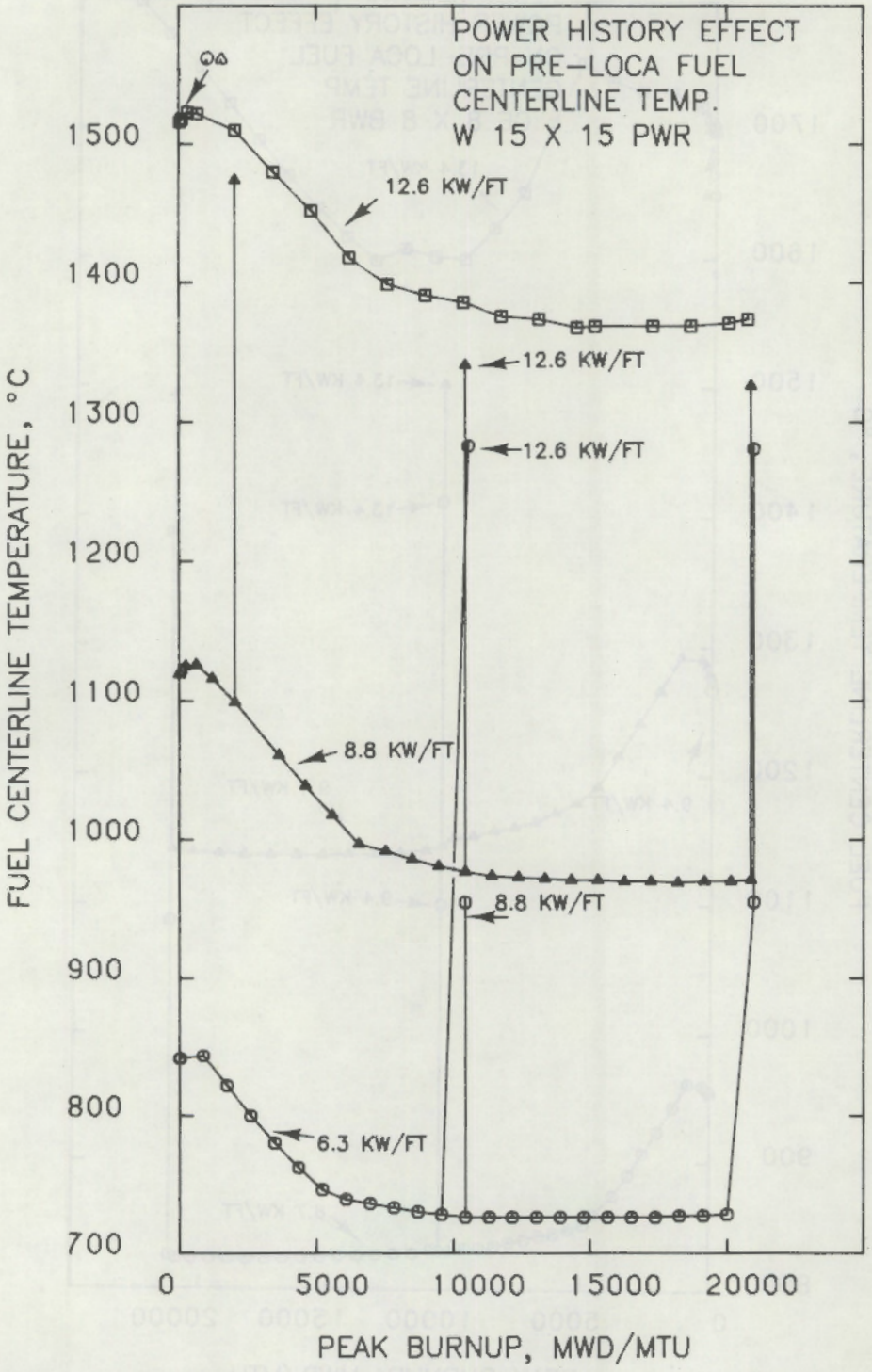

FIGURE 1. Calculated Effect of Power History on Pre-LOCA Fuel Centerline Temperature for a 15 x 15 PWR Rod with a Constant Peak-to-Average Power Ratio of 1.2

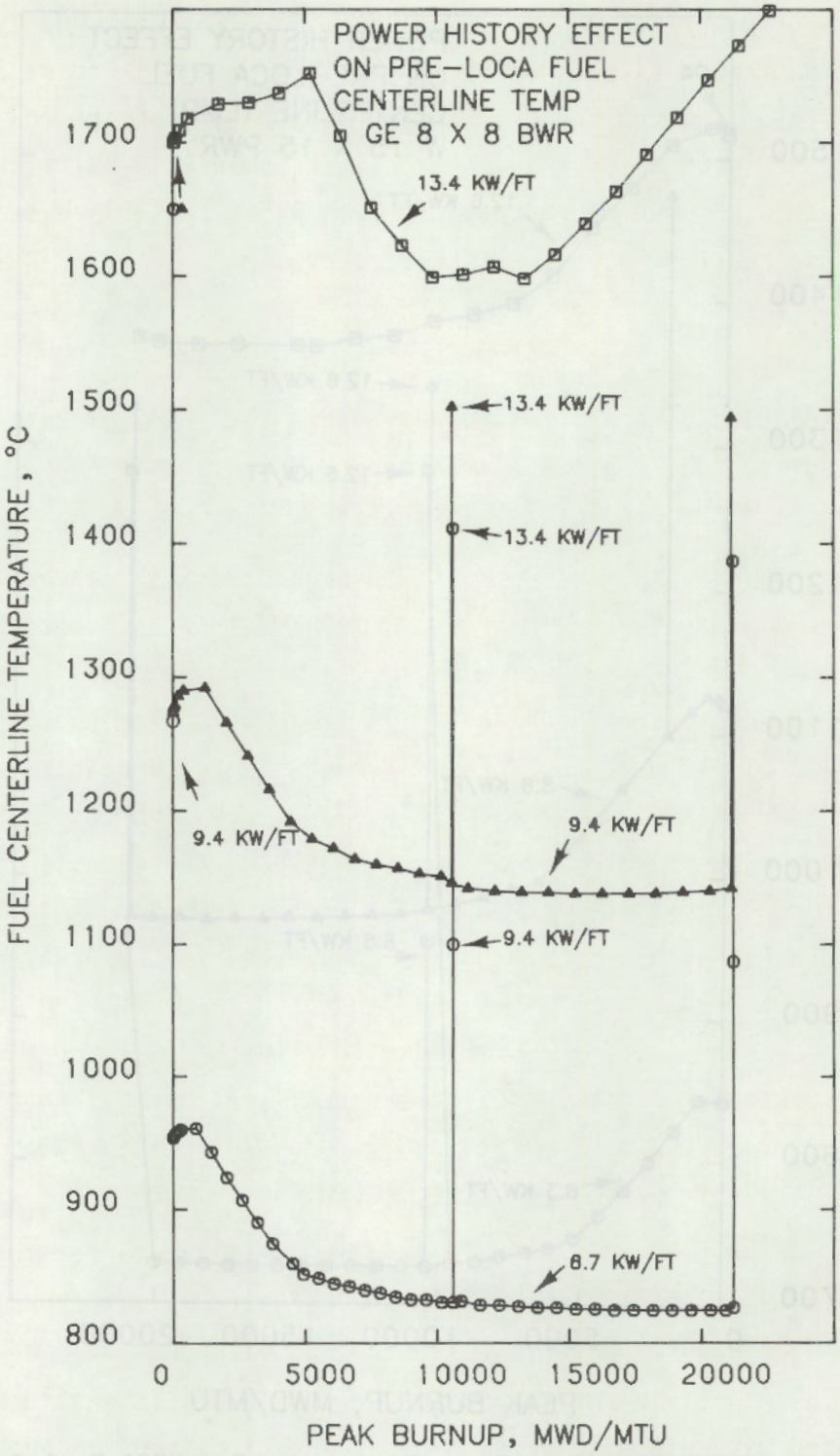

FIGURE 2. Calculated Effect of Power History on Pre-LOCA Fuel Centerline Temperature for a 8 x 8 BWR Rod with a Constant Peak-to-Average Power Ratio of 1.3

The results of power ramping while maintaining a constant rod average power and altering the axial power distribution are shown in Figure 3. At 10,000 MWd/MTU, the predicted fuel centerline temperature at the end of the ramp was low by 50°C with respect to the constant power 12.6-kW/ft curve. After the ramp at 20,000 MWd/MTU burnup, the predicted centerline temperature was 40°C below the constant power 12.6-kW/ft curve.

DISCUSSION

This discussion is directed toward developing the physical bases for the predicted effects of power history on the pre-LOCA fuel centerline temperature in Figures 1 to 3 and the predicted trends with burnup.

For the 15 x 15 PWR rod, the decrease in predicted fuel centerline temperatures that predominantly occurs prior to 7500 MWd/MTU is associated with cladding creepdown. This is characterized by the third from the last column of the appendix tables titled "CLAD RADIUS (%) PERM." A close correspondence between the trends of the numbers in this column with the predicted decreasing centerline temperature is apparent in Tables A.1, A.3 through A.5, A.9 through A.12, and A.16 through A.18. The inability of the computed fuel centerline temperatures after a power ramp to reach the peak temperatures of the 12.6-kW/ft curve shown in Figure 1 and 3 is attributed to the greater extent of creepdown that occurs in the larger hot gap associated with the lower power cases, e.g. -0.4% versus -0.9% creep in Case 1 versus Cases 4 and 5. The creepdown increases the thermal conductance due to smaller fuel-to-cladding radial gaps. Beyond 7500 MWd/MTU, fuel swelling and cladding accommodation establish stability in the predicted fuel centerline temperature.

The initial increase in predicted centerline temperature for the BWR cases shown in Figure 2 is associated with fuel densification determined by inspection of the columns of data in Tables A.2, A.6 through A.8, and A.13 through A.15. This initial increase is followed by a significant decrease that is associated with cladding creepdown. The fuel centerline temperatures stabilize for peak burnup values above 10,000 MWd/MTU in the low-power cases

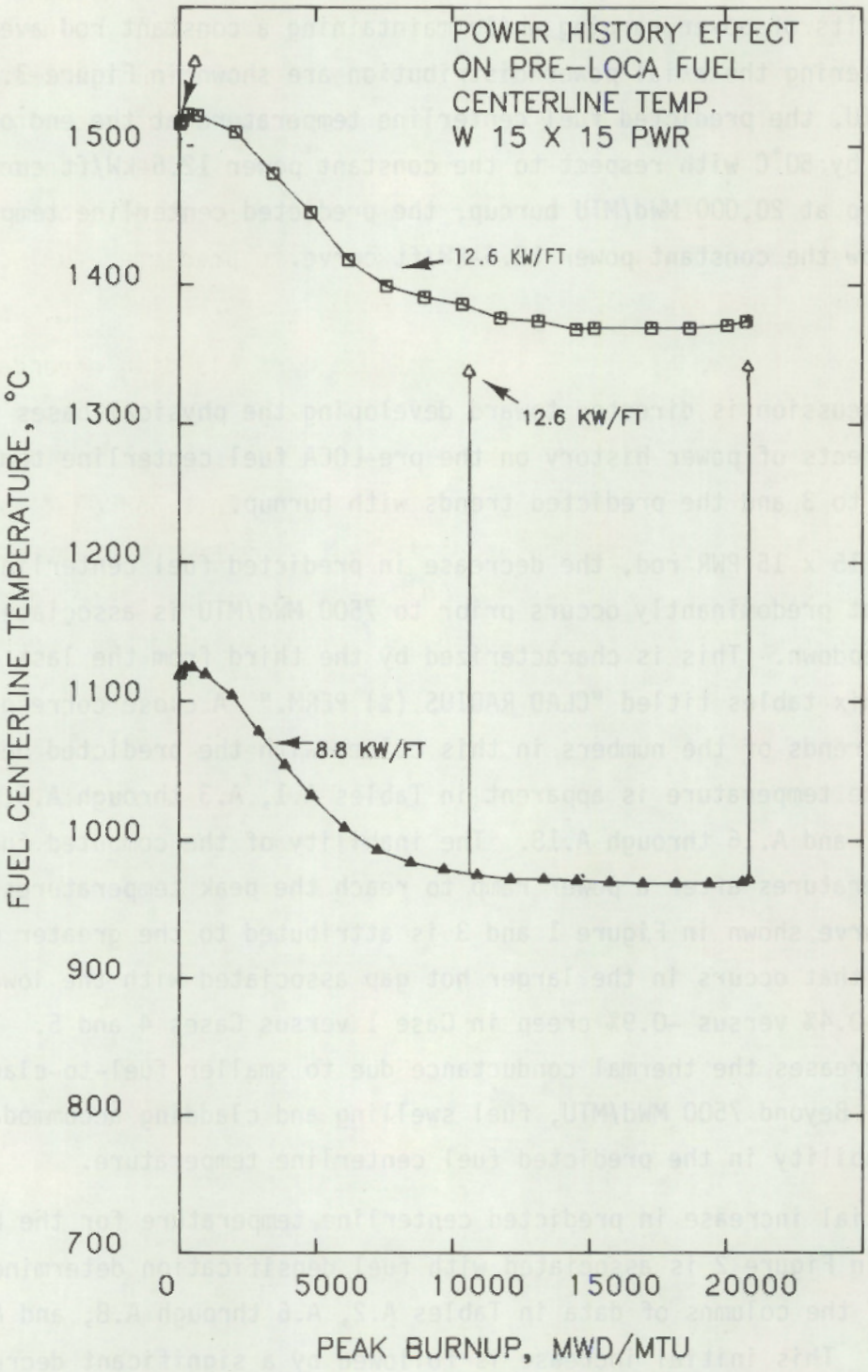

FIGURE 3. Calculated Effect of Power History on Pre-LOCA Fuel Centerline Temperature for a 15 x 15 PWR Rod with Constant Average Rod Power

but not for the constant power 13.4-kW/ft case (see Table A.2). The temperatures associated with this case are sufficiently high to permit extensive release of fission gas, which reduces the gas conductivity of the gap and results in a significant predicted increase in fuel centerline temperature beyond 10,000 MWd/MTU. Except for power ramps occurring at BOL (before the onset of cladding creepdown), all power ramps lead to predicted fuel centerline temperatures that are below the higher power cases.

An independent demonstration of the influence of cladding creepdown is displayed in Figure 4. The data used for FRAPCON-2 in Tables A.1 and A.12 were also used for GAPCON-2 as described in Tables A.19 and A.20. One of the primary differences between FRAPCON-2 and GAPCON-2 is that GAPCON-2 is a creepdown-deficient code. When the predictions of the two codes are compared (see Figure 4), it can be seen that GAPCON-2 does not predict the decreasing fuel centerline temperature that has been attributed to cladding creepdown.

The level of creepdown predicted for 0.5 and 0.7 times the LOCA-limited peak power level is on the order of 0.9% and stabilizes after a burnup of approximately 8000 MWd/MTU. This level of creepdown agrees with the 0.9% creepdown reported for light water reactor (LWR) fuel rods for burnups up to 40,000 MWd/MTU.[5]

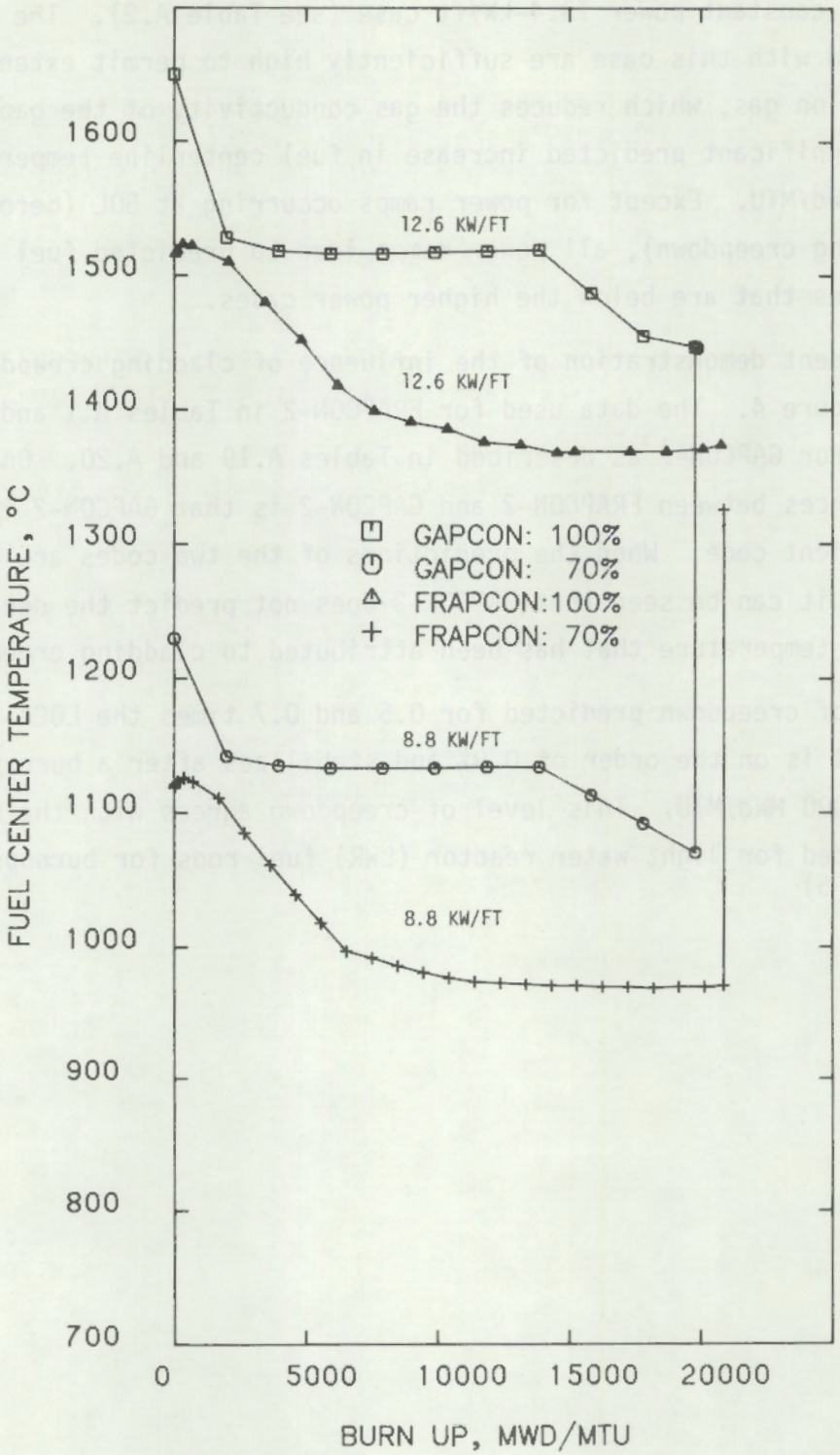

FIGURE 4. Effect of Creepdown in the FRAPCON-2 Code When Compared with the Creepdown-Deficient GAPCON-2 Code for a 15 x 15 PWR

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*Available for purchase from the NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission, Washington, DC 20555, and/or the National Technical Information Service, Springfield, VA 22161.

APPENDIX A

SUMMARY OF COMPUTER CODE OUTPUT

TABLE A.1. FRAPCON-2 Prediction for 15 x 15 PWR with 12.6 kW/ft to 20 GWd/MTM, P/A = 1.2

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF CONDUCTANCE GAP CONTACT	GAS	CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD RADIUS (%) PERM	RECOVER	AXIAL (%) TOTAL
36	0.90	41.06	1516	906	0.26E+06	.0047	.000	0.999	0.00	10.271	.000	-.026	0.000	-.006	.122	0.12
113	2.00	41.06	1518	908	0.26E+06	.0048	.000	0.999	0.14	10.192	.000	-.072	0.000	-.013	.123	0.12
321	5.00	41.06	1523	910	0.26E+06	.0052	.000	0.999	0.28	10.043	.000	-.160	0.000	-.031	.124	0.13
667	10.00	41.06	1522	910	0.26E+06	.0054	.000	0.999	0.44	9.918	.000	-.231	0.000	-.061	.127	0.13
2054	30.00	41.06	1510	906	0.26E+06	.0056	.000	0.999	0.78	9.809	.001	-.278	0.000	-.173	.132	0.14
3440	50.00	41.06	1480	893	0.26E+06	.0052	.000	0.999	0.95	9.874	.002	-.279	0.000	-.281	.134	0.14
4826	70.00	41.06	1452	881	0.25E+06	.0048	.000	0.999	1.07	9.954	.002	-.279	0.000	-.386	.136	0.15
6213	90.00	41.06	1418	864	0.25E+06	.0041	.018	0.981	1.13	10.060	.003	-.279	0.098	-.411	.182	0.14
7599	110.00	41.06	1399	853	0.25E+06	.0040	.026	0.973	1.19	10.156	.004	-.279	0.174	-.387	.203	0.20
8986	130.00	41.06	1391	849	0.24E+06	.0039	.031	0.968	1.27	10.225	.005	-.279	0.236	-.343	.200	0.26
10372	150.00	41.06	1386	849	0.24E+06	.0039	.030	0.969	1.37	10.317	.007	-.279	0.290	-.331	.226	0.30
11759	170.00	41.06	1376	844	0.24E+06	.0039	.034	0.965	1.48	10.367	.008	-.279	0.336	-.282	.201	0.35
13145	190.00	41.06	1374	846	0.24E+06	.0038	.028	0.971	1.61	10.447	.010	-.279	0.379	-.267	.222	0.39
14531	210.00	41.06	1368	844	0.24E+06	.0037	.032	0.967	1.76	10.502	.012	-.279	0.418	-.220	.200	0.43
15918	230.00	41.06	1369	846	0.24E+06	.0038	.028	0.971	1.95	10.565	.014	-.279	0.454	-.183	.198	0.47
17304	250.00	41.06	1369	848	0.24E+06	.0037	.026	0.973	2.16	10.638	.017	-.279	0.491	-.149	.197	0.51
18691	270.00	41.06	1369	849	0.24E+06	.0037	.026	0.973	2.41	10.720	.021	-.279	0.526	-.117	.197	0.55
20077	290.00	41.06	1371	851	0.25E+06	.0037	.026	0.973	2.69	10.811	.025	-.279	0.559	-.085	.196	0.58
20770	300.00	41.06	1374	854	0.25E+06	.0037	.022	0.977	2.85	10.870	.027	-.279	0.576	-.070	.200	0.60

TABLE A.2. FRAPCON-2 Prediction for 8 x 8 BWR with 13.4 kW/ft to 20 GWd/MTM, P/A = 1.3

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF GAP CONDUCTANCE CONTACT	GAS	CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD RADIUS (%) PERM	RECOVER	AXIAL (%) TOTAL
0	0.01	0.01	278	278	0.68E+05	.0108	.000	0.999	0.00	0.216	.000	0.000	0.000	0.000	.105	0.11
0	0.10	2.97	355	155	0.80E+05	.0105	.000	0.999	0.00	0.223	.000	0.000	0.000	-.001	.106	0.11
1	0.15	5.94	437	366	0.94E+05	.0102	.000	0.999	0.00	0.230	.000	0.000	0.000	-.001	.108	0.11
1	0.20	8.91	524	413	0.11E+06	.0099	.000	0.999	0.00	0.236	.000	0.000	0.000	-.001	.110	0.12
2	0.25	11.88	617	461	0.12E+06	.0095	.000	0.999	0.00	0.243	.000	0.000	0.000	-.001	.111	0.12
3	0.30	14.85	713	510	0.14E+06	.0091	.000	0.999	0.00	0.249	.000	0.000	0.000	-.002	.113	0.12
4	0.35	17.83	814	560	0.15E+06	.0088	.000	0.999	0.00	0.256	.000	0.000	0.000	-.002	.114	0.12
6	0.40	20.80	918	612	0.17E+06	.0084	.000	0.999	0.00	0.262	.000	0.000	0.000	-.002	.116	0.12
7	0.45	23.77	1026	663	0.19E+06	.0079	.000	0.999	0.00	0.268	.000	0.000	0.000	-.003	.118	0.12
9	0.50	26.74	1134	716	0.20E+06	.0075	.000	0.999	0.00	0.274	.000	0.000	0.000	-.003	.119	0.12
11	0.55	29.71	1245	769	0.22E+06	.0070	.000	0.999	0.00	0.279	.000	0.000	0.000	-.003	.121	0.12
13	0.60	32.68	1326	821	0.23E+06	.0066	.000	0.999	0.00	0.285	.000	0.000	0.000	-.004	.122	0.12
16	0.65	35.65	1417	872	0.25E+06	.0062	.000	0.999	0.00	0.290	.000	0.000	0.000	-.004	.124	0.12
18	0.70	38.62	1512	923	0.27E+06	.0058	.000	0.999	0.00	0.295	.000	0.000	0.000	-.004	.125	0.13
24	0.80	41.59	1617	974	0.29E+06	.0056	.024	0.975	0.00	0.300	.000	-.018	0.000	-.005	.173	0.16
30	0.90	43.53	1700	1014	0.30E+06	.0057	.050	0.949	0.00	0.302	.000	-.022	0.000	-.004	.236	0.22
93	2.00	43.53	1703	1018	0.30E+06	.0057	.037	0.962	0.47	0.302	.000	-.063	0.000	-.005	.203	0.20
268	5.00	43.53	1709	1026	0.30E+06	.0058	.023	0.976	0.95	0.301	.002	-.146	0.000	-.021	.152	0.16
558	10.00	43.53	1718	1033	0.31E+06	.0059	.000	0.999	1.90	0.301	.007	-.222	0.000	-.052	.137	0.14
1719	30.00	43.53	1729	1044	0.31E+06	.0061	.000	0.998	3.03	0.313	.043	-.285	0.000	-.111	.143	0.15
2880	50.00	43.53	1730	1049	0.31E+06	.0058	.030	0.968	4.15	0.335	.093	-.288	0.000	-.134	.184	0.15
4042	70.00	43.53	1737	1059	0.31E+06	.0057	.032	0.966	5.25	0.366	.153	-.288	0.000	-.161	.202	0.16
5203	90.00	43.53	1752	1075	0.32E+06	.0057	.045	0.952	6.31	0.409	.220	-.297	0.000	-.156	.212	0.18
6364	110.00	43.53	1705	1041	0.31E+06	.0055	.146	0.853	7.46	0.453	.279	-.297	0.241	-.153	.210	0.38
7526	130.00	43.53	1651	1020	0.30E+06	.0046	.126	0.871	7.66	0.486	.317	-.297	0.404	-.139	.214	0.51
8687	150.00	43.53	1623	1008	0.30E+06	.0041	.135	0.862	7.76	0.518	.348	-.297	0.525	-.134	.210	0.58
9848	170.00	43.53	1599	999	0.29E+06	.0036	.137	0.859	7.78	0.549	.375	-.297	0.618	-.126	.211	0.69
11009	190.00	43.53	1601	1006	0.30E+06	.0033	.136	0.860	7.96	0.586	.403	-.297	0.696	-.092	.214	0.79
12171	210.00	43.53	1607	1015	0.30E+06	.0030	.139	0.856	8.30	0.632	.433	-.297	0.764	-.090	.232	0.84
13332	230.00	43.53	1599	1014	0.30E+06	.0028	.149	0.846	8.64	0.677	.461	-.297	0.822	-.052	.215	0.92
14493	250.00	43.53	1616	1030	0.30E+06	.0026	.153	0.841	9.18	0.738	.491	-.297	0.875	-.002	.216	1.00
15655	270.00	43.53	1639	1049	0.31E+06	.0025	.165	0.828	10.06	0.821	.526	-.297	0.923	0.052	.216	1.08
16816	290.00	43.53	1663	1070	0.32E+06	.0024	.177	0.816	11.26	0.929	.562	-.297	0.969	0.110	.217	1.17
17977	310.00	43.53	1691	1093	0.32E+06	.0023	.190	0.802	12.78	1.067	.597	-.297	1.012	0.169	.217	1.25
19138	330.00	43.53	1719	1117	0.33E+06	.0023	.202	0.789	14.60	1.237	.631	-.297	1.053	0.231	.218	1.33
20300	350.00	43.53	1747	1142	0.34E+06	.0022	.211	0.778	16.63	1.438	.660	-.297	1.092	0.294	.218	1.41
21461	370.00	43.53	1773	1167	0.35E+06	.0021	.217	0.770	18.84	1.670	.685	-.297	1.128	0.356	.218	1.48
22622	390.00	43.53	1799	1191	0.36E+06	.0021	.222	0.763	21.19	1.932	.707	-.297	1.163	0.418	.218	1.55

TABLE A.3. FRAPCON-2 Prediction for 15 x 15 PWR with 6.3 kW/ft for 1 Day, Ramp to 12.6 kW/ft, P/A = 1.2

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF CONDUCTANCE GAP CONTACT	FRACTION OF CONDUCTANCE GAP GAS	CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD (%) PERM	CLAD (%) RADIUS RECOVER	AXIAL (%) TOTAL
0	0.01	0.01	274	274	0.67E+05	.0086	.000	0.999	0.00	6.733	.000	0.000	0.000	0.000	.070	0.10
0	0.03	2.98	343	312	0.78E+05	.0085	.000	0.999	0.00	6.986	.000	0.000	0.000	0.000	.074	0.10
0	0.06	5.96	416	352	0.89E+05	.0083	.000	0.999	0.00	7.241	.000	0.000	0.000	0.000	.078	0.11
1	0.09	8.94	493	279	0.10E+06	.0080	.000	0.999	0.00	7.498	.000	0.000	0.000	-.001	.082	0.11
1	0.12	11.92	576	436	0.11E+06	.0078	.000	0.999	0.00	7.756	.000	0.000	0.000	-.001	.085	0.11
2	0.15	14.90	663	481	0.13E+06	.0075	.000	0.999	0.00	8.015	.000	0.000	0.000	-.001	.089	0.11
3	0.18	17.88	755	526	0.14E+06	.0072	.000	0.999	0.00	8.275	.000	0.000	0.000	-.001	.093	0.11
4	0.21	20.59	842	568	0.16E+06	.0069	.000	0.999	0.00	8.514	.000	0.000	0.000	-.002	.096	0.11
14	0.50	20.59	842	566	0.16E+06	.0069	.000	0.999	0.00	8.513	.000	0.000	0.000	-.004	.096	0.11
32	1.00	23.34	933	613	0.17E+06	.0070	.000	0.999	0.00	8.730	.000	-.019	0.000	-.007	.097	0.11
35	1.03	26.32	1034	661	0.18E+06	.0064	.000	0.999	0.00	8.993	.000	-.023	0.000	-.007	.104	0.12
37	1.06	29.30	1139	711	0.20E+06	.0061	.000	0.999	0.00	9.255	.000	-.025	0.000	-.008	.108	0.12
38	1.09	32.28	1246	761	0.22E+06	.0057	.000	0.999	0.00	9.517	.000	-.026	0.000	-.008	.111	0.12
40	1.12	35.26	1329	809	0.23E+06	.0053	.000	0.999	0.01	9.771	.000	-.028	0.000	-.008	.115	0.12
42	1.15	38.24	1421	858	0.25E+06	.0050	.000	0.999	0.02	10.022	.000	-.029	0.000	-.008	.119	0.12
44	1.18	41.07	1516	906	0.26E+06	.0046	.000	0.999	0.04	10.264	.000	-.031	0.000	-.008	.122	0.12

TABLE A.4. FRAPCON-2 Prediction for 15 x 15 PWR with 6.3 kW/ft for 10 GWd/MTM, Ramp to 12.6 kW/ft, P/A = 1.2

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF GAP CONTACT	GAP CONDUCTANCE GAS	CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD RADIUS (%) PERM	CLAD RADIUS (%) RECOVER	AXIAL (%) TOTAL
0	0.01	0.01	274	274	0.67E+05	.0086	.000	0.999	0.00	6.733	.000	0.000	0.000	0.000	.070	0.10
0	0.03	2.98	343	312	0.78E+05	.0085	.000	0.999	0.00	6.986	.000	0.000	0.000	0.000	.074	0.10
0	0.06	5.96	416	352	0.89E+05	.0083	.000	0.999	0.00	7.241	.000	0.000	0.000	0.000	.078	0.11
1	0.09	8.94	493	279	0.10E+06	.0080	.000	0.999	0.00	7.498	.000	0.000	0.000	-.001	.082	0.11
1	0.12	11.92	576	436	0.11E+06	.0078	.000	0.999	0.00	7.756	.000	0.000	0.000	-.001	.085	0.11
2	0.15	14.90	663	481	0.13E+06	.0075	.000	0.999	0.00	8.015	.000	0.000	0.000	-.001	.089	0.11
3	0.18	17.88	755	526	0.14E+06	.0072	.000	0.999	0.00	8.275	.000	0.000	0.000	-.001	.093	0.11
4	0.21	20.59	842	568	0.16E+06	.0069	.000	0.999	0.00	8.514	.000	0.000	0.000	-.002	.096	0.11
14	0.50	20.59	842	568	0.16E+06	.0069	.000	0.999	0.00	8.513	.000	0.000	0.000	-.004	.096	0.11
32	1.00	20.59	842	568	0.16E+06	.0070	.000	0.999	0.00	8.494	.000	-.019	0.000	-.007	.097	0.11
866	25.00	20.59	844	570	0.16E+06	.0070	.000	0.999	0.00	8.216	.000	-.207	0.000	-.178	.101	0.13
1735	50.00	20.59	822	561	0.15E+06	.0072	.000	0.999	0.01	8.307	.000	-.228	0.000	-.349	.103	0.14
2604	75.00	20.59	800	551	0.15E+06	.0065	.000	0.999	0.02	8.452	.000	-.230	0.000	-.515	.106	0.14
3473	100.00	20.59	780	543	0.15E+06	.0058	.000	0.999	0.03	8.613	.000	-.230	0.000	-.678	.108	0.15
4342	125.00	20.59	762	536	0.15E+06	.0051	.000	0.999	0.04	8.785	.000	-.230	0.000	-.837	.110	0.15
5211	150.00	20.59	746	528	0.14E+06	.0044	.000	0.999	0.05	8.966	.000	-.230	0.000	-.873	.113	0.16
6080	175.00	20.59	739	526	0.14E+06	.0043	.020	0.979	0.05	9.008	.000	-.230	0.020	-.880	.131	0.14
6949	200.00	20.59	736	524	0.14E+06	.0042	.019	0.980	0.06	9.022	.000	-.230	0.039	-.888	.154	0.15
7818	225.00	20.59	733	522	0.14E+06	.0042	.018	0.981	0.07	9.035	.000	-.230	0.059	-.888	.169	0.16
8687	250.00	20.59	730	521	0.14E+06	.0042	.020	0.979	0.08	9.043	.000	-.230	0.078	-.882	.179	0.17
9556	275.00	20.59	728	519	0.14E+06	.0041	.023	0.976	0.09	9.060	.000	-.230	0.098	-.881	.193	0.19
10541	300.00	23.34	798	553	0.15E+06	.0042	.039	0.960	0.10	9.123	.000	-.230	0.120	-.828	.182	0.26
10543	300.03	26.32	879	594	0.16E+06	.0040	.034	0.965	0.10	9.373	.000	-.230	0.120	-.827	.239	0.31
10544	300.06	29.30	962	633	0.18E+06	.0041	.046	0.954	0.10	9.523	.000	-.230	0.120	-.827	.292	0.36
10546	300.09	32.28	1048	672	0.19E+06	.0040	.054	0.948	0.10	9.669	.000	-.230	0.120	-.827	.336	0.41
10548	300.12	35.26	1133	711	0.20E+06	.0040	.058	0.941	0.10	9.811	.000	-.230	0.120	-.826	.363	0.46
10550	300.15	38.24	1213	748	0.21E+06	.0038	.061	0.939	0.10	9.951	.000	-.230	0.120	-.826	.376	0.50
10552	300.18	41.07	1283	781	0.22E+06	.0035	.061	0.938	0.10	10.075	.000	-.230	0.120	-.825	.379	0.54

TABLE A.5. FRAPCON-2 Prediction for 15 x 15 PWR with 6.3 kW/ft for 20 GWd/MTM, Ramp to 12.6 kW/ft, P/A = 1.2

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF GAP CONDUCTANCE CONTACT	GAS	CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD RADIUS (%) PERM	RECOVER	AXIAL (%) TOTAL
0	0.01	0.01	274	274	0.67E+05	.0086	.000	0.999	0.00	6.733	.000	0.000	0.000	0.000	.070	0.10
0	0.03	2.98	343	312	0.78E+05	.0085	.000	0.999	0.00	6.986	.000	0.000	0.000	0.000	.074	0.10
0	0.06	5.96	416	352	0.89E+05	.0083	.000	0.999	0.00	7.241	.000	0.000	0.000	0.000	.078	0.11
1	0.09	8.94	493	393	0.10E+06	.0080	.000	0.999	0.00	7.498	.000	0.000	0.000	-.001	.082	0.11
1	0.12	11.92	576	436	0.11E+06	.0078	.000	0.999	0.00	7.756	.000	0.000	0.000	-.001	.085	0.11
2	0.15	14.90	663	481	0.13E+06	.0075	.000	0.999	0.00	8.015	.000	0.000	0.000	-.001	.089	0.11
3	0.18	17.48	755	526	0.14E+06	.0072	.000	0.999	0.00	8.275	.000	0.000	0.000	-.001	.093	0.11
4	0.21	20.59	842	568	0.16E+06	.0069	.000	0.999	0.00	8.514	.000	0.000	0.000	-.002	.096	0.11
14	0.50	20.59	842	568	0.16E+06	.0069	.000	0.999	0.00	8.513	.000	0.000	0.000	-.004	.096	0.11
32	1.00	20.59	842	568	0.16E+06	.0070	.000	0.999	0.00	8.494	.000	-.019	0.000	-.007	.097	0.11
866	25.00	20.59	844	570	0.16E+06	.0076	.000	0.999	0.00	8.210	.000	-.207	0.000	-.178	.101	0.13
1735	50.00	20.59	822	561	0.15E+06	.0072	.000	0.999	0.01	8.307	.000	-.228	0.000	-.349	.103	0.14
2604	75.00	20.59	800	551	0.15E+06	.0065	.000	0.999	0.02	8.452	.000	-.230	0.000	-.515	.106	0.14
3473	100.00	20.59	780	543	0.15E+06	.0058	.000	0.999	0.03	8.613	.000	-.230	0.000	-.678	.108	0.15
4342	125.00	20.59	762	536	0.15E+06	.0051	.000	0.999	0.04	8.785	.000	-.230	0.000	-.837	.110	0.15
5211	150.00	20.59	746	528	0.14E+06	.0044	.000	0.999	0.05	8.966	.000	-.230	0.000	-.873	.113	0.16
6080	175.00	20.59	739	526	0.14E+06	.0043	.020	0.979	0.05	9.008	.000	-.230	0.020	-.880	.131	0.14
6949	200.00	20.59	736	524	0.14E+06	.0042	.019	0.980	0.06	9.022	.000	-.230	0.039	-.888	.154	0.15
7818	225.00	20.59	733	522	0.14E+06	.0042	.018	0.981	0.07	9.035	.000	-.230	0.059	-.888	.169	0.16
8687	250.00	20.59	730	521	0.14E+06	.0042	.020	0.979	0.08	9.043	.000	-.230	0.078	-.882	.179	0.17
9556	275.00	20.59	728	519	0.14E+06	.0041	.023	0.976	0.09	9.060	.000	-.230	0.098	-.881	.193	0.19
10425	300.00	20.59	726	554	0.14E+06	.0042	.027	0.972	0.10	9.070	.000	-.230	0.117	-.849	.177	0.20
11294	325.00	20.59	726	519	0.14E+06	.0042	.023	0.976	0.10	9.081	.001	-.230	0.137	-.829	.175	0.22
12136	350.00	20.59	726	519	0.14E+06	.0042	.023	0.977	0.11	9.094	.001	-.230	0.156	-.812	.175	0.24
13032	375.00	20.59	726	519	0.14E+06	.0042	.022	0.977	0.12	9.108	.001	-.230	0.176	-.794	.175	0.26
13901	400.00	20.59	726	519	0.14E+06	.0041	.022	0.977	0.13	9.122	.001	-.230	0.195	-.776	.175	0.28
14770	425.00	20.59	726	520	0.14E+06	.0041	.022	0.977	0.14	9.137	.001	-.230	0.215	-.759	.175	0.29
15639	450.00	20.59	726	520	0.14E+06	.0041	.022	0.977	0.14	9.152	.001	-.230	0.234	-.741	.175	0.31
16509	475.00	20.59	726	521	0.14E+06	.0041	.022	0.976	0.15	9.167	.001	-.230	0.253	-.724	.175	0.33
17378	500.00	20.59	726	521	0.14E+06	.0041	.022	0.976	0.16	9.183	.001	-.230	0.273	-.706	.175	0.35
18247	525.00	20.59	727	521	0.14E+06	.0041	.022	0.976	0.17	9.199	.001	-.230	0.292	-.688	.175	0.37
19116	550.00	20.59	727	522	0.14E+06	.0041	.022	0.976	0.18	9.215	.002	-.230	0.312	-.670	.175	0.38
19985	575.00	20.59	728	522	0.14E+06	.0040	.022	0.976	0.19	9.232	.002	-.230	0.331	-.652	.175	0.40
20970	600.00	23.34	799	557	0.15E+06	.0041	.036	0.963	0.19	9.397	.002	-.230	0.353	-.603	.182	0.53
20971	600.03	26.32	882	599	0.16E+06	.0040	.034	0.964	0.20	9.569	.002	-.230	0.353	-.603	.240	0.53
20973	600.06	29.80	966	638	0.18E+06	.0041	.046	0.953	0.20	9.725	.002	-.230	0.353	-.603	.293	0.58
20974	600.09	32.28	1051	677	0.19E+06	.0040	.054	0.945	0.20	9.879	.002	-.230	0.353	-.602	.336	0.63
20976	600.12	35.26	1134	716	0.20E+06	.0039	.059	0.940	0.20	10.029	.002	-.230	0.353	-.602	.362	0.68
20978	600.15	38.24	1213	753	0.21E+06	.0037	.061	0.938	0.20	10.173	.002	-.230	0.353	-.601	.373	0.72
20980	600.18	41.07	1281	786	0.22E+06	.0035	.062	0.937	0.20	10.302	.002	-.230	0.353	-.601	.376	0.75

TABLE A.6. FRAPCON-2 Prediction for 8 x 8 BWR with 6.7 kW/ft for 1 Day, Ramp to 13.4 kW/ft, P/A = 1.3

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF GAP CONDUCTANCE CONTACT	GAS	CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD RADIUS (%) PERM	RECOVER	AXIAL (%) TOTAL
0	0.01	0.01	278	278	0.68E+05	.0108	.000	0.999	0.00	0.216	.000	0.000	0.000	0.000	.105	0.11
0	0.10	2.97	355	322	0.80E+05	.0105	.000	0.999	0.00	0.223	.000	0.000	0.000	-.001	.106	0.11
1	0.15	5.94	437	366	0.94E+05	.0102	.000	0.999	0.00	0.230	.000	0.000	0.000	-.001	.108	0.11
1	0.20	8.91	524	413	0.11E+06	.0099	.000	0.999	0.00	0.236	.000	0.000	0.000	-.001	.110	0.12
2	0.25	11.88	617	461	0.12E+06	.0095	.000	0.999	0.00	0.243	.000	0.000	0.000	-.001	.111	0.12
3	0.30	14.85	713	510	0.14E+06	.0091	.000	0.999	0.00	0.249	.000	0.000	0.000	-.002	.113	0.12
4	0.35	17.83	814	560	0.15E+06	.0088	.000	0.999	0.00	0.256	.000	0.000	0.000	-.002	.114	0.12
6	0.40	20.80	918	612	0.17E+06	.0084	.000	0.999	0.00	0.262	.000	0.000	0.000	-.002	.116	0.12
7	0.45	21.79	954	629	0.17E+06	.0082	.000	0.999	0.00	0.264	.000	0.000	0.000	-.003	.117	0.12
23	1.00	21.79	955	629	0.17E+06	.0083	.000	0.999	0.00	0.264	.000	-.015	0.000	-.006	.117	0.12
24	1.03	23.77	1026	664	0.19E+06	.0080	.000	0.999	0.00	0.268	.000	-.016	0.000	-.006	.118	0.12
25	1.06	26.74	1136	717	0.20E+06	.0076	.000	0.999	0.00	0.273	.000	-.017	0.000	-.006	.120	0.12
29	1.09	29.71	1247	769	0.22E+06	.0071	.000	0.999	0.00	0.279	.000	-.018	0.000	-.007	.121	0.12
28	1.12	32.68	1327	821	0.23E+06	.0067	.000	0.999	0.01	0.284	.000	-.020	0.000	-.002	.123	0.12
29	1.15	35.65	1418	872	0.25E+06	.0063	.000	0.999	0.02	0.290	.000	-.021	0.000	-.007	.124	0.13
31	1.18	38.62	2758	924	0.27E+06	.0058	.000	0.999	0.04	0.295	.000	-.022	0.000	-.007	.126	0.13
32	1.21	41.59	1617	974	0.29E+06	.0057	.022	0.977	0.08	0.299	.000	-.024	0.000	-.007	.171	0.16
34	1.24	43.53	1700	1014	0.30E+06	.0056	.049	0.950	0.14	0.302	.000	-.025	0.000	-.007	.237	0.22

TABLE A.7. FRAPCON-2 Prediction for 8 x 8 BWR with 6.7 kW/ft for 10 GWd/MTM, Ramp to 13.4 kW/ft, P/A = 1.3

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF CONDUCTANCE GAP CONTACT	FRACTION OF CONDUCTANCE GAP GAS	CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD RADIUS (%) PERM	CLAD RADIUS (%) RECOVER	AXIAL (%) TOTAL
0	0.01	0.01	278	278	0.68E+05	.0108	.000	0.999	0.00	0.216	.000	0.000	0.000	0.000	.105	0.11
0	0.10	2.97	355	322	0.80E+05	.0105	.000	0.999	0.00	0.223	.000	0.000	0.000	-.001	.106	0.11
1	0.15	5.94	437	366	0.94E+05	.0102	.000	0.999	0.00	0.230	.000	0.000	0.000	-.001	.108	0.11
1	0.20	8.91	524	413	0.11E+06	.0099	.000	0.999	0.00	0.236	.000	0.000	0.000	-.001	.110	0.12
2	0.25	11.88	617	461	0.12E+06	.0095	.000	0.999	0.00	0.243	.000	0.000	0.000	-.001	.111	0.12
3	0.30	14.85	713	510	0.14E+06	.0091	.000	0.999	0.00	0.249	.000	0.000	0.000	-.002	.113	0.12
4	0.35	17.83	814	560	0.15E+06	.0088	.000	0.999	0.00	0.256	.000	0.000	0.000	-.002	.114	0.12
6	0.40	20.80	918	612	0.17E+06	.0084	.000	0.999	0.00	0.262	.000	0.000	0.000	-.002	.116	0.12
7	0.45	21.79	954	629	0.17E+06	.0082	.000	0.999	0.00	0.264	.000	0.000	0.000	-.003	.117	0.12
23	1.00	21.79	955	629	0.17E+06	.0083	.000	0.999	0.00	0.264	.000	-.015	0.000	-.006	.117	0.12
52	2.00	21.79	956	629	0.17E+06	.0084	.000	0.999	0.00	0.263	.000	-.032	0.000	-.012	.118	0.12
139	5.00	21.79	958	631	0.17E+06	.0086	.000	0.999	0.00	0.262	.000	-.076	0.000	-.030	.120	0.13
285	10.00	21.79	960	631	0.17E+06	.0088	.000	0.999	0.00	0.261	.000	-.130	0.000	-.059	.122	0.13
866	30.00	21.79	961	632	0.18E+06	.0091	.000	0.999	0.01	0.259	.000	-.221	0.000	-.172	.126	0.14
1447	50.00	21.79	963	624	0.17E+06	.0087	.000	0.999	0.01	0.260	.000	-.240	0.000	-.281	.127	0.14
2028	70.00	21.79	928	617	0.17E+06	.0082	.000	0.999	0.02	0.261	.000	-.245	0.000	-.390	.128	0.15
2609	90.00	21.79	907	609	0.17E+06	.0077	.000	0.999	0.02	0.263	.000	-.245	0.000	-.499	.128	0.15
3191	110.00	21.79	890	602	0.17E+06	.0071	.000	0.999	0.03	0.265	.001	-.246	0.000	-.608	.129	0.15
3772	130.00	21.79	874	595	0.16E+06	.0066	.000	0.999	0.03	0.267	.001	-.246	0.000	-.717	.129	0.16
4533	150.00	21.79	859	588	0.16E+06	.0061	.000	0.999	0.04	0.269	.001	-.246	0.000	-.765	.130	0.16
4934	170.00	21.79	851	586	0.16E+06	.0059	.000	0.999	0.04	0.270	.002	-.246	0.000	-.769	.130	0.16
5515	190.00	21.79	848	584	0.16E+06	.0058	.000	0.999	0.05	0.270	.002	-.246	0.000	-.772	.130	0.17
6096	210.00	21.79	844	582	0.16E+06	.0058	.026	0.973	0.05	0.270	.003	-.246	0.013	-.786	.152	0.17
6678	230.00	21.79	842	581	0.16E+06	.0058	.025	0.974	0.06	0.271	.003	-.246	0.027	-.795	.169	0.17
7259	250.00	21.79	839	579	0.16E+06	.0058	.025	0.974	0.06	0.271	.004	-.246	0.040	-.795	.179	0.18
7840	270.00	21.79	837	578	0.16E+06	.0058	.028	0.971	0.07	0.271	.005	-.246	0.053	-.793	.188	0.19
8421	290.00	21.79	834	577	0.16E+06	.0058	.032	0.967	0.08	0.272	.006	-.246	0.067	-.793	.197	0.19
9002	310.00	21.79	832	576	0.16E+06	.0057	.036	0.963	0.08	0.272	.006	-.246	0.080	-.776	.190	0.21
9583	330.00	21.79	832	577	0.16E+06	.0058	.034	0.965	0.09	0.273	.007	-.246	0.093	-.775	.199	0.21
10165	350.00	21.79	830	576	0.16E+06	.0057	.037	0.961	0.09	0.273	.008	-.246	0.106	-.753	.187	0.23
10600	365.00	21.79	830	576	0.16E+06	.0057	.032	0.967	0.10	0.274	.009	-.246	0.116	-.742	.187	0.24
10601	365.03	23.77	891	606	0.17E+06	.0057	.047	0.952	0.10	0.276	.009	-.246	0.116	-.742	.228	0.27
10602	365.06	26.74	984	649	0.18E+06	.0058	.071	0.928	0.10	0.280	.009	-.246	0.116	-.742	.286	0.32
10604	365.09	29.71	1078	693	0.19E+06	.0057	.088	0.911	0.10	0.283	.009	-.246	0.116	-.742	.323	0.37
10605	365.12	32.68	1167	734	0.21E+06	.0055	.097	0.902	0.10	0.287	.009	-.246	0.116	-.741	.337	0.42
10606	365.15	35.65	1245	772	0.22E+06	.0052	.100	0.899	0.10	0.290	.009	-.246	0.116	-.741	.339	0.45
10608	365.18	38.62	1318	779	0.23E+06	.0049	.101	0.898	0.10	0.293	.009	-.246	0.116	-.741	.338	0.49
10610	365.21	41.59	1370	841	0.24E+06	.0046	.102	0.897	0.10	0.295	.009	-.246	0.116	-.740	.336	0.52
10611	365.24	43.53	1411	861	0.25E+06	.0043	.099	0.900	0.10	0.297	.009	-.246	0.116	-.740	.327	0.54
10669	366.24	43.53	1396	857	0.25E+06	.0041	.091	0.907	0.20	0.300	.018	-.246	0.118	-.740	.227	0.52

TABLE A.8. FRAPCON-2 Prediction for 8 x 8 BWR with 6.7 kW/ft for 20 GWd/MTM, Ramp to 13.4 kW/ft, P/A = 1.3

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF CONDUCTANCE GAP CONTACT	GAS	CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD RADIUS (%) PERM	RECOVER	AXIAL (%) TOTAL
0	0.01	0.01	278	278	0.68E+05	.0108	.000	0.999	0.00	0.216	.000	0.000	0.000	0.000	.105	0.11
0	0.10	2.97	355	322	0.80E+05	.0105	.000	0.999	0.00	0.223	.000	0.000	0.000	-.001	.106	0.11
1	0.15	5.94	437	366	0.94E+05	.0102	.000	0.999	0.00	0.230	.000	0.000	0.000	-.001	.108	0.11
1	0.20	8.91	524	413	0.11E+06	.0099	.000	0.999	0.00	0.236	.000	0.000	0.000	-.001	.110	0.12
2	0.25	11.88	617	461	0.12E+06	.0095	.000	0.999	0.00	0.243	.000	0.000	0.000	-.001	.111	0.12
3	0.30	14.85	713	510	0.14E+06	.0091	.000	0.999	0.00	0.249	.000	0.000	0.000	-.002	.113	0.12
4	0.35	17.83	814	560	0.15E+06	.0088	.000	0.999	0.00	0.256	.000	0.000	0.000	-.002	.114	0.12
6	0.40	20.80	918	612	0.17E+06	.0084	.000	0.999	0.00	0.262	.000	0.000	0.000	-.002	.116	0.12
7	0.45	21.79	954	629	0.17E+06	.0082	.000	0.999	0.00	0.264	.000	0.000	0.000	-.003	.117	0.12
23	1.00	21.79	955	629	0.17E+06	.0083	.000	0.999	0.00	0.264	.000	-.015	0.000	-.006	.117	0.12
52	2.00	21.79	956	629	0.17E+06	.0084	.000	0.999	0.00	0.263	.000	-.032	0.000	-.012	.118	0.12
139	5.00	21.79	958	631	0.17E+06	.0086	.000	0.999	0.00	0.262	.000	-.076	0.000	-.030	.120	0.13
285	10.00	21.79	960	631	0.17E+06	.0088	.000	0.999	0.00	0.261	.000	-.130	0.000	-.059	.122	0.13
866	30.00	21.79	961	632	0.18E+06	.0091	.000	0.999	0.01	0.259	.000	-.221	0.000	-.172	.126	0.14
1447	50.00	21.79	943	624	0.17E+06	.0087	.000	0.999	0.01	0.260	.000	-.240	0.000	-.281	.127	0.14
2028	70.00	21.79	924	617	0.17E+06	.0082	.000	0.999	0.02	0.261	.000	-.245	0.000	-.390	.128	0.15
2609	90.00	21.79	907	609	0.17E+06	.0077	.000	0.999	0.02	0.263	.000	-.245	0.000	-.499	.128	0.15
3191	110.00	21.79	890	602	0.17E+06	.0071	.000	0.999	0.03	0.265	.001	-.246	0.000	-.608	.129	0.15
3772	130.00	21.79	874	595	0.16E+06	.0066	.000	0.999	0.03	0.267	.001	-.246	0.000	-.717	.129	0.16
4353	150.00	21.79	859	588	0.16E+06	.0061	.000	0.999	0.04	0.269	.001	-.246	0.000	-.765	.130	0.16
4934	170.00	21.79	851	586	0.16E+06	.0059	.000	0.999	0.04	0.270	.002	-.246	0.000	-.769	.130	0.16
5515	190.00	21.79	848	584	0.16E+06	.0058	.000	0.999	0.05	0.270	.002	-.246	0.000	-.792	.130	0.17
6096	210.00	21.79	844	582	0.16E+06	.0058	.026	0.973	0.05	0.270	.003	-.246	0.013	-.786	.152	0.17
6678	230.00	21.79	842	581	0.16E+06	.0058	.025	0.974	0.06	0.271	.003	-.246	0.027	-.795	.169	0.17
7259	250.00	21.79	839	579	0.16E+06	.0058	.025	0.974	0.06	0.271	.004	-.246	0.040	-.795	.179	0.18
7840	270.00	21.79	837	578	0.16E+06	.0058	.028	0.971	0.07	0.271	.005	-.246	0.053	-.793	.188	0.19
8421	290.00	21.79	834	577	0.16E+06	.0058	.032	0.967	0.08	0.272	.006	-.246	0.067	-.793	.197	0.19
9002	310.00	21.79	832	576	0.16E+06	.0057	.036	0.963	0.08	0.272	.006	-.246	0.080	-.776	.190	0.21
9583	330.00	21.79	832	577	0.16E+06	.0058	.034	0.965	0.09	0.273	.007	-.246	0.093	-.775	.199	0.21
10165	350.00	21.79	830	576	0.16E+06	.0057	.037	0.961	0.09	0.273	.008	-.246	0.106	-.753	.187	0.23
10600	365.00	21.79	830	576	0.16E+06	.0057	.032	0.967	0.10	0.274	.009	-.246	0.116	-.742	.187	0.24
10891	375.00	21.79	831	577	0.16E+06	.0057	.030	0.969	0.10	0.274	.009	-.246	0.122	-.737	.187	0.25
11617	400.00	21.79	828	576	0.16E+06	.0057	.033	0.965	0.10	0.274	.011	-.246	0.139	-.721	.185	0.26
12344	425.00	21.79	828	576	0.16E+06	.0057	.033	0.966	0.11	0.275	.012	-.246	0.155	-.707	.185	0.27
13070	450.00	21.79	827	576	0.16E+06	.0058	.033	0.965	0.12	0.275	.013	-.246	0.171	-.692	.185	0.29
13797	475.00	21.79	826	576	0.16E+06	.0057	.033	0.965	0.13	0.276	.015	-.246	0.188	-.678	.185	0.30
14523	500.00	21.79	826	576	0.16E+06	.0057	.033	0.965	0.13	0.277	.016	-.246	0.204	-.663	.185	0.32
15250	525.00	21.79	825	576	0.16E+06	.0057	.033	0.965	0.14	0.277	.018	-.246	0.220	-.649	.185	0.33
15976	550.00	21.79	825	576	0.16E+06	.0057	.034	0.965	0.15	0.278	.020	-.246	0.237	-.634	.185	0.35
16703	575.00	21.79	824	577	0.16E+06	.0054	.034	0.964	0.15	0.279	.022	-.246	0.253	-.620	.185	0.36
17429	600.00	21.79	824	577	0.16E+06	.0056	.034	0.964	0.16	0.280	.024	-.246	0.269	-.605	.185	0.38
18156	625.00	21.79	824	577	0.16E+06	.0057	.034	0.964	0.17	0.281	.026	-.246	0.285	-.591	.185	0.39
18882	650.00	21.79	824	577	0.16E+06	.0057	.034	0.964	0.17	0.282	.028	-.246	0.302	-.576	.185	0.41
19609	675.00	21.79	824	578	0.16E+06	.0057	.035	0.964	0.18	0.283	.030	-.246	0.318	-.561	.185	0.42
20335	700.00	21.79	824	578	0.16E+06	.0056	.035	0.963	0.19	0.284	.032	-.246	0.334	-.546	.185	0.44
20916	720.00	21.79	824	578	0.16E+06	.0056	.034	0.964	0.19	0.284	.034	-.246	0.347	-.535	.186	0.45
21207	730.00	21.79	826	579	0.16E+06	.0056	.031	0.967	0.20	0.285	.035	-.246	0.353	-.529	.187	0.45
21208	730.03	23.77	884	608	0.17E+06	.0057	.049	0.949	0.20	0.288	.035	-.246	0.353	-.529	.227	0.49
21209	730.06	26.74	973	650	0.18E+06	.0056	.074	0.924	0.20	0.292	.035	-.246	0.354	-.529	.284	0.54
21210	730.09	29.71	1065	693	0.19E+06	.0055	.092	0.906	0.20	0.295	.035	-.246	0.354	-.529	.321	0.58
21211	730.12	32.68	1150	734	0.21E+06	.0054	.101	0.897	0.20	0.299	.035	-.246	0.354	-.528	.336	0.62
21213	730.15	35.65	1226	772	0.22E+06	.0052	.105	0.894	0.20	0.302	.035	-.246	0.354	-.528	.338	0.66
21214	730.18	38.62	1297	807	0.23E+06	.0049	.106	0.893	0.20	0.305	.035	-.246	0.354	-.527	.336	0.69
21216	730.21	41.59	1349	841	0.24E+06	.0045	.107	0.892	0.20	0.308	.035	-.246	0.354	-.527	.335	0.73
21218	730.24	43.53	1387	861	0.25E+06	.0042	.104	0.895	0.20	0.310	.035	-.246	0.354	-.527	.325	0.74
21276	731.24	43.53	1380	861	0.25E+06	.0040	.103	0.896	0.42	0.324	.071	-.246	0.355	-.526	.228	0.73

TABLE A.9. FRAPCON-2 Prediction for 15 x 15 PWR with 8.8 kW/ft for 1 Day, Ramp to 12.6 kW/ft P/A = 1.2

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF CONDUCTANCE GAP CONTACT	FRACTION OF CONDUCTANCE GAP GAS	CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD RADIUS (%) PERM	CLAD RADIUS (%) RECOVER	AXIAL (%) TOTAL
0	0.01	0.01	274	274	0.67E+05	.0086	.000	0.999	0.00	6.733	.000	0.000	0.000	0.000	.070	0.10
0	0.03	2.98	343	312	0.78E+05	.0085	.000	0.999	0.00	6.986	.000	0.000	0.000	0.000	.074	0.10
0	0.06	5.96	416	352	0.89E+05	.0083	.000	0.999	0.00	7.241	.000	0.000	0.000	0.000	.078	0.11
1	0.09	8.94	493	393	0.10E+06	.0080	.000	0.999	0.00	7.498	.000	0.000	0.000	-.001	.082	0.11
1	0.12	11.92	576	436	0.11E+06	.0078	.000	0.999	0.00	7.756	.000	0.000	0.000	-.001	.085	0.11
2	0.15	14.90	663	481	0.13E+06	.0075	.000	0.999	0.00	8.015	.000	0.000	0.000	-.001	.089	0.11
3	0.18	17.88	755	526	0.14E+06	.0072	.000	0.999	0.00	8.275	.000	0.000	0.000	-.001	.093	0.11
4	0.21	20.86	850	573	0.16E+06	.0070	.000	0.999	0.00	8.538	.000	0.000	0.000	-.002	.097	0.11
5	0.24	23.84	949	621	0.17E+06	.0066	.000	0.999	0.00	8.801	.000	0.000	0.000	-.002	.100	0.11
7	0.27	26.82	1051	669	0.19E+06	.0063	.000	0.999	0.00	9.066	.000	0.000	0.000	-.002	.104	0.11
8	0.30	28.76	1119	701	0.20E+06	.0060	.000	0.999	0.00	9.238	.000	0.000	0.000	-.002	.107	0.12
18	0.50	28.76	1119	701	0.20E+06	.0060	.000	0.999	0.00	9.237	.000	0.000	0.000	-.004	.107	0.12
42	1.00	28.76	1121	702	0.20E+06	.0061	.000	0.999	0.00	9.200	.000	-.027	0.000	-.007	.107	0.12
44	1.03	31.29	1211	744	0.21E+06	.0058	.000	0.999	0.01	9.424	.000	-.029	0.000	-.007	.110	0.12
45	1.06	34.27	1317	794	0.23E+06	.0055	.000	0.999	0.01	9.682	.000	-.031	0.000	-.007	.114	0.12
47	1.09	37.25	1391	842	0.24E+06	.0051	.000	0.999	0.02	9.932	.000	-.033	0.000	-.008	.118	0.12
49	1.12	40.23	1488	892	0.26E+06	.0047	.000	0.999	0.03	10.188	.000	-.034	0.000	-.008	.121	0.12
52	1.15	41.09	1516	907	0.26E+06	.0046	.000	0.999	0.05	10.256	.000	-.036	0.000	-.008	.122	0.12
121	2.15	41.07	1513	908	0.26E+06	.0048	.000	0.999	0.14	10.186	.000	-.076	0.000	-.014	.123	0.12
129	2.30	30.79	1145	732	0.21E+06	.0062	.000	0.999	0.16	9.264	.000	-.080	0.000	-.015	.110	0.12
132	2.40	20.86	817	569	0.16E+06	.0073	.000	0.999	0.16	8.393	.000	-.081	0.000	-.016	.097	0.12
134	2.50	10.93	532	420	0.11E+06	.0082	.000	0.999	0.16	7.550	.000	-.082	0.000	-.016	.085	0.11
134	2.60	0.99	295	287	0.70E+06	.0089	.000	0.999	0.16	6.729	.000	-.082	0.000	-.017	.073	0.11
136	2.70	10.93	532	420	0.11E+06	.0082	.000	0.999	0.16	7.551	.000	-.082	0.000	-.018	.085	0.11
140	2.80	20.86	817	569	0.16E+06	.0073	.000	0.999	0.16	8.393	.000	-.084	0.000	-.019	.097	0.12
145	2.90	30.79	1144	731	0.21E+06	.0061	.000	0.999	0.16	9.257	.000	-.088	0.000	-.019	.110	0.12
152	3.00	41.07	1518	907	0.26E+06	.0049	.000	0.999	0.17	10.167	.000	-.092	0.000	-.020	.123	0.12

TABLE A.10. FRAPCON-2 Prediction for 15 x 15 PWR with 8.8 kW/ft for 2 GWd/MTM, Ramp to 12.6 kW/ft, P/A = 1.2

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF GAP CONDUCTANCE CONTACT	FRACTION OF GAP CONDUCTANCE GAS	CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD RADIUS (%) PERM	CLAD RADIUS (%) RECOVER	AXIAL (%) TOTAL
0	0.01	0.01	274	274	0.67E+05	.0086	.000	0.999	0.00	6.733	.000	0.000	0.000	0.000	.070	0.10
0	0.03	2.98	343	276	0.78E+05	.0085	.000	0.999	0.00	6.986	.000	0.000	0.000	0.000	.074	0.10
0	0.06	5.96	416	352	0.89E+05	.0083	.000	0.999	0.00	7.241	.000	0.000	0.000	-.001	.082	0.11
1	0.09	8.94	493	393	0.10E+06	.0080	.000	0.999	0.00	7.498	.000	0.000	0.000	-.001	.085	0.11
1	0.12	11.92	576	436	0.11E+06	.0078	.000	0.999	0.00	7.756	.000	0.000	0.000	-.001	.085	0.11
2	0.15	14.90	663	481	0.13E+06	.0075	.000	0.999	0.00	8.015	.000	0.000	0.000	-.001	.089	0.11
3	0.18	17.88	755	526	0.14E+06	.0072	.000	0.999	0.00	8.275	.000	0.000	0.000	-.001	.093	0.11
4	0.21	20.86	850	573	0.16E+06	.0070	.000	0.999	0.00	8.538	.000	0.000	0.000	-.002	.097	0.11
5	0.24	23.84	749	621	0.17E+06	.0066	.000	0.999	0.00	8.801	.000	0.000	0.000	-.002	.100	0.11
7	0.27	26.82	1051	669	0.19E+06	.0063	.000	0.999	0.00	9.066	.000	0.000	0.000	-.002	.104	0.11
8	0.30	28.76	1119	701	0.20E+06	.0060	.000	0.999	0.00	9.238	.000	0.000	0.000	-.002	.107	0.12
18	0.50	28.76	1119	701	0.20E+06	.0060	.000	0.999	0.00	9.237	.000	0.000	0.000	-.004	.107	0.12
42	1.00	28.76	1121	702	0.20E+06	.0061	.000	0.999	0.00	9.200	.000	-.027	0.000	-.007	.107	0.12
91	2.00	28.76	1122	702	0.20E+06	.0063	.000	0.999	0.01	9.162	.000	-.055	0.000	-.014	.107	0.12
236	5.00	28.76	1125	703	0.20E+06	.0065	.000	0.999	0.01	9.071	.000	-.120	0.000	-.034	.109	0.12
625	13.00	28.76	1126	703	0.20E+06	.0068	.000	0.999	0.02	8.943	.000	-.209	0.000	-.086	.111	0.13
1207	25.00	28.76	1116	700	0.20E+06	.0068	.000	0.999	0.03	8.901	.000	-.248	0.000	-.163	.113	0.13
2033	42.00	28.76	1099	693	0.19E+06	.0066	.000	0.999	0.03	8.925	.000	-.257	0.000	-.270	.119	0.14
2034	42.03	31.29	1172	728	0.21E+06	.0059	.000	0.999	0.03	9.209	.000	-.268	0.000	-.270	.122	0.14
2036	42.06	34.27	1275	777	0.22E+06	.0055	.000	0.999	0.04	9.441	.000	-.268	0.000	-.270	.122	0.14
2038	42.09	37.25	1354	824	0.24E+06	.0052	.000	0.999	0.04	9.673	.000	-.278	0.000	-.270	.126	0.14
2040	42.12	40.23	1446	873	0.25E+06	.0048	.000	0.999	0.05	9.902	.000	-.278	0.000	-.271	.129	0.14
2042	42.15	41.07	1474	887	0.26E+06	.0047	.000	0.999	0.05	9.967	.000	-.278	0.000	-.271	.130	0.14

TABLE A.11. FRAPCON-2 Prediction for 15 x 15 PWR with 8.8 kW/ft for 10 GWd/MTM, Ramp to 12.6 kW/ft, P/A = 1.2

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF CONDUCTANCE GAP		CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD RADIUS (%) PERM	CLAD RADIUS (%) RECOVER	AXIAL (%) TOTAL
							CONTACT	GAS								
0	0.01	0.01	274	274	0.67E+05	.0086	.000	0.999	0.00	6.733	.000	0.000	0.000	0.000	.070	0.10
0	0.03	2.98	343	312	0.78E+05	.0085	.000	0.999	0.00	6.986	.000	0.000	0.000	0.000	.074	0.10
0	0.06	5.96	416	352	0.89E+05	.0083	.000	0.999	0.00	7.241	.000	0.000	0.000	0.000	.078	0.11
1	0.09	8.94	493	393	0.10E+06	.0080	.000	0.999	0.00	7.498	.000	0.000	0.000	-.001	.082	0.11
1	0.12	11.92	576	436	0.11E+06	.0078	.000	0.999	0.00	7.756	.000	0.000	0.000	-.001	.085	0.11
2	0.15	14.90	663	481	0.13E+06	.0075	.000	0.999	0.00	8.015	.000	0.000	0.000	-.001	.089	0.11
3	0.18	17.88	755	526	0.14E+06	.0072	.000	0.999	0.00	8.275	.000	0.000	0.000	-.001	.093	0.11
4	0.21	20.86	850	573	0.16E+06	.0070	.000	0.999	0.00	8.536	.000	0.000	0.000	-.002	.097	0.11
5	0.24	23.84	949	621	0.17E+06	.0066	.000	0.999	0.00	8.801	.000	0.000	0.000	-.002	.100	0.11
7	0.27	26.82	1051	669	0.19E+06	.0063	.000	0.999	0.00	9.066	.000	0.000	0.000	-.002	.104	0.11
8	0.30	28.76	1119	701	0.20E+06	.0060	.000	0.999	0.00	9.238	.000	0.000	0.000	-.002	.107	0.12
18	0.50	28.76	1119	701	0.20E+06	.0060	.000	0.999	0.00	9.237	.000	0.000	0.000	-.004	.107	0.12
42	1.00	28.76	1121	702	0.20E+06	.0061	.000	0.999	0.00	9.200	.000	-.027	0.000	-.007	.107	0.12
139	3.00	28.76	1123	703	0.20E+06	.0064	.000	0.999	0.01	9.126	.000	-.080	0.000	-.020	.108	0.12
382	8.00	28.76	1126	704	0.20E+06	.0067	.000	0.999	0.01	9.007	.000	-.164	0.000	-.054	.110	0.12
722	15.00	28.76	1123	702	0.20E+06	.0068	.000	0.999	0.02	8.938	.000	-.220	0.000	-.099	.112	0.13
1693	35.00	28.76	1111	698	0.20E+06	.0068	.000	0.999	0.03	8.884	.000	-.255	0.000	-.227	.114	0.14
2664	55.00	28.76	1085	688	0.19E+06	.0063	.000	0.999	0.04	8.965	.000	-.258	0.000	-.351	.116	0.14
3635	75.00	28.76	1061	678	0.19E+06	.0058	.000	0.999	0.04	9.060	.000	-.258	0.000	-.472	.118	0.15
4605	95.00	28.76	1039	669	0.19E+06	.0053	.000	0.999	0.05	9.163	.000	-.258	0.000	-.592	.119	0.15
5576	115.00	28.76	1018	661	0.18E+06	.0049	.000	0.999	0.05	9.273	.000	-.258	0.000	-.710	.121	0.15
6547	135.00	28.76	997	652	0.18E+06	.0042	.000	0.999	0.06	9.406	.000	-.258	0.024	-.715	.123	0.16
7518	155.00	28.76	992	649	0.18E+06	.0042	.019	0.980	0.07	9.425	.000	-.258	0.047	-.721	.142	0.14
8489	175.00	28.76	986	647	0.18E+06	.0041	.018	0.981	0.08	9.450	.000	-.258	0.070	-.732	.170	0.15
9460	195.00	28.76	981	644	0.18E+06	.0041	.018	0.981	0.09	9.496	.000	-.258	0.093	-.729	.182	0.16
10432	215.00	28.76	977	642	0.18E+06	.0042	.021	0.978	0.09	9.537	.000	-.258	0.116	-.716	.189	0.18
10432	215.03	31.29	1053	677	0.19E+06	.0041	.033	0.967	0.10	9.677	.000	-.258	0.116	-.716	.242	0.22
10434	215.06	34.27	1146	718	0.20E+06	.0041	.045	0.954	0.10	9.824	.000	-.258	0.116	-.718	.303	0.28
10436	215.09	37.25	1239	759	0.22E+06	.0040	.054	0.954	0.10	9.970	.000	-.258	0.116	-.717	.350	0.34
10438	215.12	40.23	1329	799	0.23E+06	.0040	.059	0.941	0.10	10.110	.000	-.258	0.116	-.717	.376	0.39
10440	215.15	41.07	1341	806	0.23E+06	.0038	.057	0.943	0.10	10.144	.000	-.258	0.116	-.716	.380	0.39
10510	216.15	41.07	1329	802	0.23E+06	.0037	.054	0.946	0.14	10.142	.001	-.258	0.118	-.710	.261	0.37
10517	216.30	30.79	1002	659	0.18E+06	.0037	.000	0.999	0.14	9.540	.001	-.258	0.118	-.711	.127	0.18
10521	216.40	20.86	730	523	0.14E+06	.0047	.000	0.999	0.14	8.791	.001	-.258	0.118	-.711	.116	0.18
10523	216.50	10.93	493	398	0.10E+06	.0053	.000	0.999	0.14	8.057	.001	-.258	0.118	-.712	.105	0.18
10523	216.60	0.99	292	285	0.70E+05	.0089	.000	0.999	0.14	7.331	.001	-.258	0.118	-.713	.094	0.17
10525	216.70	10.93	493	398	0.10E+06	.0053	.000	0.999	0.14	8.059	.001	-.258	0.118	-.713	.105	0.18
10528	216.80	20.86	730	523	0.14E+06	.0047	.000	0.999	0.14	8.795	.001	-.258	0.118	-.714	.116	0.18
10533	216.90	30.79	1001	659	0.18E+06	.0037	.000	0.999	0.14	9.545	.001	-.258	0.119	-.714	.127	0.18
10540	217.00	41.07	1303	798	0.23E+06	.0033	.033	0.966	0.14	10.134	.001	-.258	0.119	-.714	.248	0.27

TABLE A.12. FRAPCON-2 Prediction for 15 x 15 PWR with 8.8 kW/ft for 20 GWd/MTM, Ramp to 12.6 kW/ft, P/A = 1.2

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF GAP CONDUCTANCE CONTACT	GAS	CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SHELL (%)	CLAD RADIUS (%) PERM	RECOVER	AXIAL (%) TOTAL
8	0.30	28.76	1119	701	0.20E+06	.0060	.000	0.999	0.00	9.238	.000	0.000	0.000	-.002	.107	0.12
18	0.50	28.76	1119	701	0.20E+06	.0060	.000	0.999	0.00	9.237	.000	0.000	0.000	-.004	.107	0.12
42	1.00	28.76	1121	702	0.20E+06	.0061	.000	0.999	0.00	9.200	.000	-.027	0.000	-.007	.107	0.12
139	3.00	28.76	1123	703	0.20E+06	.0064	.000	0.999	0.01	9.124	.000	-.080	0.000	-.020	.108	0.12
382	8.00	28.76	1126	704	0.20E+06	.0067	.000	0.999	0.01	9.007	.000	-.164	0.000	-.054	.110	0.12
722	15.00	28.76	1123	702	0.20E+06	.0068	.000	0.999	0.02	8.938	.000	-.220	0.000	-.099	.112	0.13
1693	35.00	28.76	1111	698	0.20E+06	.0068	.000	0.999	0.03	4.884	.000	-.255	0.000	-.227	.114	0.14
2664	55.00	28.76	1088	688	0.19E+06	.0063	.000	0.999	0.04	8.965	.000	-.258	0.000	-.351	.116	0.14
3635	75.00	28.76	1061	676	0.19E+06	.0058	.000	0.999	0.04	9.060	.000	-.258	0.000	-.472	.118	0.15
4605	95.00	28.76	1039	669	0.19E+06	.0053	.000	0.999	0.05	9.163	.000	-.258	0.000	-.592	.119	0.15
5576	115.00	28.76	1018	661	0.18E+06	.0049	.000	0.999	0.05	9.273	.000	-.258	0.000	-.710	.121	0.15
6547	135.00	28.76	997	652	0.18E+06	.0042	.000	0.999	0.06	9.406	.000	-.258	0.028	-.715	.123	0.16
7518	155.00	28.76	992	649	0.18E+06	.0042	.019	0.980	0.07	9.425	.000	-.258	0.047	-.721	.142	0.16
8489	175.00	28.76	986	647	0.18E+06	.0041	.018	0.981	0.08	9.450	.000	-.258	0.070	-.732	.170	0.15
9460	195.00	28.76	981	644	0.18E+06	.0041	.018	0.981	0.09	9.496	.000	-.258	0.093	-.739	.182	0.16
10432	215.00	28.76	977	642	0.18E+06	.0042	.021	0.978	0.09	9.537	.000	-.258	0.116	-.718	.189	0.18
11402	235.00	28.76	974	641	0.18E+06	.0042	.023	0.976	0.10	9.560	.001	-.258	0.138	-.695	.184	0.19
12373	255.00	28.76	973	641	0.18E+06	.0042	.022	0.977	0.11	9.571	.001	-.258	0.160	-.675	.184	0.21
13344	275.00	28.76	972	641	0.18E+06	.0042	.022	0.977	0.12	9.587	.001	-.258	0.182	-.655	.184	0.23
14314	295.00	28.76	971	641	0.18E+06	.0042	.022	0.977	0.13	9.604	.001	-.258	0.204	-.635	.184	0.25
15285	315.00	28.76	971	641	0.18E+06	.0041	.022	0.977	0.14	9.623	.001	-.258	0.226	-.616	.184	0.27
16256	335.00	28.76	970	641	0.18E+06	.0041	.022	0.977	0.15	9.642	.001	-.258	0.248	-.596	.184	0.29
17227	355.00	28.76	970	641	0.18E+06	.0041	.022	0.977	0.16	9.661	.001	-.258	0.270	-.577	.184	0.31
18198	375.00	28.76	969	642	0.18E+06	.0040	.022	0.977	0.17	9.681	.001	-.258	0.292	-.557	.184	0.33
19169	395.00	28.76	970	642	0.18E+06	.0040	.022	0.977	0.18	9.701	.002	-.258	0.313	-.537	.184	0.35
20140	415.00	28.76	970	642	0.18E+06	.0040	.022	0.977	0.19	9.722	.002	-.258	0.335	-.517	.184	0.37
20866	430.00	28.76	971	643	0.18E+06	.0041	.021	0.978	0.19	9.740	.002	-.258	0.351	-.502	.185	0.39
20870	430.03	31.29	1047	678	0.19E+06	.0040	.032	0.967	0.20	9.877	.002	-.258	0.352	-.502	.236	0.44
20871	430.06	34.27	1136	719	0.20E+06	.0040	.045	0.954	0.20	10.030	.002	-.258	0.352	-.502	.298	0.49
20873	430.09	37.29	1227	760	0.22E+06	.0040	.054	0.945	0.20	10.183	.002	-.258	0.352	-.501	.345	0.55
20875	430.12	40.23	1314	799	0.23E+06	.0039	.059	0.940	0.20	10.331	.002	-.258	0.352	-.501	.371	0.60
20877	430.15	41.07	1326	806	0.23E+06	.0037	.057	0.942	0.20	10.365	.002	-.258	0.352	-.501	.356	0.60

TABLE A.13. FRAPCON-2 Prediction for 8 x 8 BWR with 9.4 kW/ft for 1 Day, Ramp to 13.4 kW/ft, P/A = 1.3

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF CONDUCTANCE GAP CONTACT	GAS	CUMMULATIVE ROD FIS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SHELL (%)	CLAD (%) PERM	RADIUS RECOVER	AXIAL (%) TOTAL
0	0.01	0.01	276	276	0.68E+05	.0108	.000	0.999	0.00	0.216	.000	0.000	0.000	0.000	.105	0.11
0	0.10	2.97	391	382	0.80E+05	.0105	.000	0.999	0.00	0.223	.000	0.000	0.000	-.001	.106	0.11
1	0.15	5.94	437	366	0.94E+05	.0102	.000	0.999	0.00	0.230	.000	0.000	0.000	-.001	.108	0.11
1	0.20	8.91	524	413	0.11E+06	.0101	.000	0.999	0.00	0.236	.000	0.000	0.000	-.001	.110	0.12
2	0.25	11.88	617	461	0.12E+06	.0095	.000	0.999	0.00	0.243	.000	0.000	0.000	-.001	.111	0.12
3	0.30	14.15	713	510	0.14E+06	.0091	.000	0.999	0.00	0.249	.000	0.000	0.000	-.002	.113	0.12
4	0.35	17.83	814	560	0.15E+06	.0088	.000	0.999	0.00	0.256	.000	0.000	0.000	-.002	.114	0.12
6	0.40	20.80	918	612	0.17E+06	.0084	.000	0.999	0.00	0.262	.000	0.000	0.000	-.002	.116	0.12
7	0.45	23.77	1026	663	0.19E+06	.0079	.000	0.999	0.00	0.268	.000	0.000	0.000	-.003	.118	0.12
9	0.50	26.74	1134	716	0.20E+06	.0075	.000	0.999	0.00	0.274	.000	0.000	0.000	-.003	.119	0.12
11	0.55	29.71	1245	769	0.22E+06	.0070	.000	0.999	0.00	0.279	.000	0.000	0.000	-.003	.121	0.12
13	0.60	30.50	1274	783	0.22E+06	.0069	.000	0.999	0.00	0.281	.000	0.000	0.000	-.004	.121	0.12
29	1.00	30.50	1277	784	0.22E+06	.0070	.000	0.999	0.01	0.280	.000	-.020	0.000	-.006	.122	0.12
31	1.03	32.68	1327	821	0.23E+06	.0067	.000	0.999	0.01	0.284	.000	-.022	0.000	-.006	.123	0.12
32	1.06	35.65	1418	878	0.25E+06	.0066	.000	0.999	0.02	0.289	.000	-.023	0.000	-.007	.124	0.13
34	1.09	38.62	1514	934	0.27E+06	.0058	.000	0.999	0.04	0.295	.000	-.025	0.000	-.007	.126	0.13
35	1.12	41.59	1617	974	0.29E+06	.0057	.022	0.977	0.08	0.299	.000	-.026	0.000	-.007	.166	0.16
37	1.15	43.53	1700	1015	0.30E+06	.0056	.049	0.950	0.14	0.302	.000	-.027	0.000	-.007	.235	0.22
95	2.19	43.53	1703	1018	0.30E+06	.0057	.037	0.961	0.50	0.302	.000	-.064	0.000	-.007	.205	0.20

TABLE A.14. FRAPCON-2 Prediction for 8 x 8 BWR with 9.4 kW/ft for 10 GWd/MTM, Ramp to 13.4 kW/ft, P/A = 1.3

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF CONDUCTANCE GAP		CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD (%) PERM	RADIUS (%) RECOVER	AXIAL (%) TOTAL
							CONTACT	GAS								
0	0.01	0.01	278	278	0.68E+05	.0108	.000	0.999	0.00	0.216	.000	0.000	0.000	0.000	.105	0.11
0	0.10	2.97	351	322	0.80E+05	.0105	.000	0.999	0.00	0.223	.000	0.000	0.000	-.001	.106	0.11
1	0.15	5.94	437	366	0.94E+05	.0102	.000	0.999	0.00	0.230	.000	0.000	0.000	-.001	.108	0.11
1	0.20	8.91	524	413	0.11E+06	.0101	.000	0.999	0.00	0.236	.000	0.000	0.000	-.001	.110	0.12
2	0.25	11.88	617	461	0.12E+06	.0095	.000	0.999	0.00	0.243	.000	0.000	0.000	-.001	.111	0.12
3	0.30	14.15	713	510	0.14E+06	.0091	.000	0.999	0.00	0.249	.000	0.000	0.000	-.002	.113	0.12
4	0.35	17.83	814	560	0.15E+06	.0088	.000	0.999	0.00	0.256	.000	0.000	0.000	-.002	.114	0.12
6	0.40	20.80	918	612	0.17E+06	.0084	.000	0.999	0.00	0.262	.000	0.000	0.000	-.002	.116	0.12
7	0.45	23.77	1026	663	0.19E+06	.0079	.000	0.999	0.00	0.268	.000	0.000	0.000	-.003	.118	0.12
9	0.50	26.74	1134	716	0.20E+06	.0075	.000	0.999	0.00	0.274	.000	0.000	0.000	-.003	.119	0.12
11	0.55	29.71	1245	769	0.22E+06	.0070	.000	0.999	0.00	0.279	.000	0.000	0.000	-.003	.121	0.12
13	0.60	30.50	1274	783	0.22E+06	.0069	.000	0.999	0.00	0.281	.000	0.000	0.000	-.004	.121	0.12
29	1.00	30.50	1277	784	0.22E+06	.0070	.000	0.999	0.01	0.280	.000	-.020	0.000	-.006	.122	0.12
70	2.00	30.50	1279	785	0.22E+06	.0071	.000	0.999	0.02	0.280	.000	-.046	0.000	-.013	.123	0.13
192	5.00	30.50	1286	787	0.22E+06	.0074	.000	0.999	0.04	0.278	.000	-.107	0.000	-.031	.125	0.13
396	10.00	30.50	1290	789	0.22E+06	.0077	.000	0.999	0.06	0.277	.000	-.175	0.000	-.061	.128	0.13
1209	30.00	30.50	1292	789	0.23E+06	.0080	.000	0.999	0.12	0.275	.001	-.258	0.000	-.174	.134	0.14
2023	50.00	30.50	1266	779	0.22E+06	.0076	.000	0.999	0.14	0.276	.002	-.268	0.000	-.284	.135	0.15
2836	70.00	30.50	1241	769	0.22E+06	.0071	.000	0.999	0.15	0.278	.004	-.269	0.000	-.393	.136	0.15
3650	90.00	30.50	1216	759	0.22E+06	.0066	.000	0.999	0.16	0.279	.005	-.269	0.000	-.502	.136	0.15
4464	110.00	30.50	1192	749	0.21E+06	.0060	.000	0.999	0.16	0.281	.006	-.269	0.000	-.554	.137	0.16
5277	130.00	30.50	1179	744	0.21E+06	.0059	.000	0.999	0.17	0.283	.008	-.269	0.000	-.563	.137	0.16
6091	150.00	30.50	1172	741	0.21E+06	.0058	.025	0.973	0.17	0.283	.009	-.269	0.026	-.586	.173	0.16
6905	170.00	30.50	1164	736	0.21E+06	.0058	.024	0.975	0.18	0.284	.011	-.269	0.050	-.589	.191	0.18
7718	190.00	30.50	1160	734	0.21E+06	.0057	.032	0.966	0.19	0.286	.013	-.269	0.073	-.576	.194	0.19
8532	210.00	30.50	1157	733	0.21E+06	.0057	.035	0.964	0.20	0.288	.015	-.269	0.095	-.574	.208	0.21
9346	230.00	30.50	1153	731	0.21E+06	.0057	.041	0.958	0.21	0.289	.017	-.269	0.117	-.556	.205	0.22
10159	250.00	30.50	1151	731	0.21E+06	.0057	.040	0.958	0.22	0.290	.019	-.269	0.138	-.555	.214	0.23
10566	260.00	30.50	1146	729	0.21E+06	.0056	.040	0.959	0.23	0.290	.021	-.269	0.148	-.554	.215	0.24
10567	260.03	32.68	1220	762	0.22E+06	.0056	.060	0.938	0.23	0.293	.021	-.269	0.148	-.554	.266	0.28
10569	260.06	35.65	1324	808	0.23E+06	.0055	.084	0.915	0.23	0.296	.021	-.269	0.148	-.553	.322	0.34
10570	260.09	38.62	1384	849	0.24E+06	.0055	.096	8.903	0.23	0.300	.021	-.269	0.148	-.553	.344	0.38
10572	260.12	41.59	1462	888	0.26E+06	.0052	.101	0.898	0.24	0.303	.022	-.269	0.148	-.553	.351	0.42
10574	260.15	43.53	1502	909	0.26E+06	.0049	.098	0.900	0.25	0.305	.023	-.269	0.149	-.552	.340	0.44
10632	261.15	43.53	1488	904	0.26E+06	.0047	.091	0.907	0.43	0.310	.038	-.269	0.151	-.550	.338	0.45

TABLE A.15. FRAPCON-2 Prediction for 8 x 8 BWR with 9.4 kW/ft for 20 GWd/MTM, Ramp to 13.4 kW/ft, P/A = 1.3

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF CONDUCTANCE GAP		CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD RADIUS (%) PERM	CLAD RADIUS (%) RECOVER	AXIAL (%) TOTAL
							CONTACT	GAS								
0	0.01	0.01	278	278	0.68E+05	.0108	.000	0.999	0.00	0.216	.000	0.000	0.000	0.000	.109	0.11
0	0.10	2.97	351	322	0.80E+05	.0105	.000	0.999	0.00	0.223	.000	0.000	0.000	-.001	.106	0.11
1	0.15	5.94	437	366	0.94E+05	.0102	.000	0.999	0.00	0.230	.000	0.000	0.000	-.001	.108	0.11
1	0.20	8.91	524	413	0.11E+06	.0101	.000	0.999	0.00	0.236	.000	0.000	0.000	-.001	.110	0.12
2	0.25	11.88	617	461	0.12E+06	.0095	.000	0.999	0.00	0.243	.000	0.000	0.000	-.001	.111	0.12
3	0.30	14.15	713	510	0.14E+06	.0091	.000	0.999	0.00	0.249	.000	0.000	0.000	-.002	.113	0.12
4	0.35	17.83	814	560	0.15E+06	.0088	.000	0.999	0.00	0.256	.000	0.000	0.000	-.002	.114	0.12
6	0.40	20.80	918	612	0.17E+06	.0084	.000	0.999	0.00	0.262	.000	0.000	0.000	-.002	.116	0.12
7	0.45	23.77	1026	663	0.19E+06	.0079	.000	0.999	0.00	0.268	.000	0.000	0.000	-.003	.118	0.12
9	0.50	26.74	1134	716	0.20E+06	.0075	.000	0.999	0.00	0.274	.000	0.000	0.000	-.003	.119	0.12
11	0.55	29.71	1245	769	0.22E+06	.0070	.000	0.999	0.00	0.279	.000	0.000	0.000	-.003	.121	0.12
13	0.60	30.50	1274	783	0.22E+06	.0069	.000	0.999	0.00	0.281	.000	0.000	0.000	-.004	.121	0.12
29	1.00	30.50	1277	784	0.22E+06	.0070	.000	0.999	0.01	0.280	.000	-.020	0.000	-.006	.122	0.12
70	2.00	30.50	1279	785	0.22E+06	.0071	.000	0.999	0.02	0.280	.000	-.046	0.000	-.013	.123	0.13
192	5.00	30.50	1286	787	0.22E+06	.0074	.000	0.999	0.04	0.278	.000	-.107	0.000	-.031	.125	0.13
396	10.00	30.50	1290	789	0.22E+06	.0077	.000	0.999	0.06	0.277	.000	-.175	0.000	-.061	.128	0.13
1209	30.00	30.50	1292	789	0.23E+06	.0080	.000	0.999	0.12	0.275	.001	-.258	0.000	-.174	.134	0.14
2023	50.00	30.50	1286	779	0.22E+06	.0076	.000	0.999	0.14	0.276	.002	-.268	0.000	-.284	.135	0.15
2836	70.00	30.50	1241	769	0.22E+06	.0071	.000	0.999	0.15	0.278	.004	-.269	0.000	-.393	.136	0.15
3650	90.00	30.50	1216	759	0.22E+06	.0066	.000	0.999	0.16	0.279	.005	-.269	0.000	-.502	.136	0.15
4464	110.00	30.50	1192	749	0.21E+06	.0060	.000	0.999	0.16	0.281	.006	-.269	0.000	-.554	.137	0.16
5277	130.00	30.50	1179	744	0.21E+06	.0059	.000	0.999	0.17	0.283	.008	-.269	0.000	-.563	.137	0.16
6091	150.00	30.50	1172	741	0.21E+06	.0058	.025	0.973	0.17	0.283	.009	-.269	0.026	-.586	.173	0.16
6905	170.00	30.50	1164	736	0.21E+06	.0058	.024	0.975	0.18	0.284	.011	-.269	0.050	-.589	.191	0.18
7718	190.00	30.50	1160	734	0.21E+06	.0057	.032	0.966	0.19	0.286	.013	-.269	0.073	-.576	.194	0.19
8532	210.00	30.50	1157	733	0.21E+06	.0057	.035	0.964	0.20	0.288	.015	-.269	0.095	-.574	.208	0.21
9346	230.00	30.50	1153	731	0.21E+06	.0057	.041	0.958	0.21	0.289	.017	-.269	0.117	-.556	.205	0.22
10159	250.00	30.50	1151	731	0.21E+06	.0057	.040	0.958	0.22	0.290	.019	-.269	0.138	-.555	.214	0.23
10566	260.00	30.50	1146	729	0.21E+06	.0056	.040	0.959	0.23	0.290	.021	-.269	0.148	-.554	.215	0.24
11176	275.00	30.50	1142	728	0.21E+06	.0056	.042	0.956	0.24	0.291	.023	-.269	0.163	-.531	.200	0.25
12193	300.00	30.50	1140	728	0.21E+06	.0055	.040	0.958	0.25	0.293	.026	-.269	0.188	-.506	.195	0.26
13210	325.00	30.50	1139	729	0.21E+06	.0055	.038	0.960	0.27	0.294	.031	-.269	0.212	-.484	.194	0.30
14227	350.00	30.50	1139	729	0.21E+06	.0056	.038	0.960	0.30	0.296	.035	-.269	0.237	-.462	.194	0.33
15244	375.00	30.50	1138	731	0.21E+06	.0056	.039	0.959	0.32	0.299	.041	-.269	0.260	-.441	.194	0.35
16261	400.00	30.50	1138	731	0.21E+06	.0055	.039	0.959	0.34	0.301	.046	-.269	0.284	-.420	.194	0.37
17279	425.00	30.50	1138	732	0.21E+06	.0055	.040	0.958	0.37	0.304	.053	-.269	0.307	-.399	.194	0.39
18296	450.00	30.50	1138	733	0.21E+06	.0055	.041	0.957	0.41	0.308	.060	-.269	0.330	-.377	.194	0.41
19313	475.00	30.50	1139	735	0.21E+06	.0054	.042	0.956	0.44	0.311	.068	-.269	0.354	-.356	.194	0.44
20330	500.00	30.50	1140	737	0.21E+06	.0054	.043	0.955	0.48	0.315	.077	-.269	0.377	-.334	.195	0.46
21143	520.00	30.50	1142	739	0.21E+06	.0054	.042	0.956	0.51	0.319	.086	-.269	0.395	-.314	.195	0.48
21151	520.15	43.53	1494	919	0.27E+06	.0049	.113	0.885	0.56	0.337	.092	-.269	0.395	-.314	.380	0.48
21209	521.15	43.53	1492	923	0.27E+06	.0047	.117	0.881	1.00	0.367	.152	-.269	0.397	-.311	.240	0.67

TABLE A.16. FRAPCON-2 Prediction for 15 x 15 PWR with 8.8 kW/ft for 1 Day, Ramp to 12.6 kW/ft, Constant Rod Average Power

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF CONDUCTANCE GAP CONTACT	GAS	CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD RADIUS (%) PERM	RECOVER	AXIAL (%) TOTAL
0	0.01	0.01	274	274	0.67E+05	.0086	.000	0.999	0.00	6.733	.000	0.000	0.000	0.000	.070	0.10
0	0.03	3.61	358	321	0.80E+05	.0085	.000	0.999	0.00	7.035	.000	0.000	0.000	0.000	.075	0.10
0	0.06	7.21	446	369	0.94E+05	.0082	.000	0.999	0.00	7.339	.000	0.000	0.000	0.000	.079	0.11
1	0.09	10.82	545	420	0.11E+06	.0079	.000	0.999	0.00	7.645	.000	0.000	0.000	-.001	.084	0.11
2	0.12	14.43	649	473	0.13E+06	.0075	.000	0.999	0.00	7.952	.000	0.000	0.000	-.001	.088	0.11
3	0.15	18.04	760	528	0.14E+06	.0072	.000	0.999	0.00	8.261	.000	0.000	0.000	-.001	.093	0.11
4	0.18	21.64	876	585	0.16E+06	.0069	.000	0.999	0.00	8.571	.000	0.000	0.000	-.001	.097	0.11
5	0.21	25.25	997	643	0.18E+06	.0065	.000	0.999	0.00	8.883	.000	0.000	0.000	-.002	.102	0.11
7	0.24	28.74	1118	701	0.20E+06	.0060	.000	0.999	0.00	9.185	.000	0.000	0.000	-.002	.106	0.11
19	0.80	28.74	1118	701	0.20E+06	.0060	.000	0.999	0.00	9.184	.000	0.000	0.000	-.004	.106	0.12
43	1.00	28.74	1120	702	0.20E+06	.0062	.000	0.999	0.00	9.147	.000	-.028	0.000	-.007	.106	0.12
49	1.10	31.26	1352	810	0.23E+06	.0053	.000	0.999	0.01	9.061	.000	-.034	0.000	-.008	.108	0.12
56	1.20	40.95	1510	903	0.26E+06	.0047	.000	0.999	0.04	8.978	.000	-.039	0.000	-.008	.110	0.12
112	2.00	40.95	1512	904	0.26E+06	.0048	.000	0.999	0.12	9.749	.000	-.071	0.000	-.014	.111	0.12

TABLE A.17. FRAPCON-2 Prediction for 15 x 15 PWR with 8.8 kW/ft for 10 GWd/MTM, Ramp to 12.6 kW/ft, Constant Rod Average Power

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF GAP CONTACT	GAP CONDUCTANCE GAS	CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD RADIUS (%) PERM	CLAD RADIUS (%) RECOVER	AXIAL (%) TOTAL
0	0.01	0.01	274	274	0.67E+05	.0086	.000	0.999	0.00	6.733	.000	0.000	0.000	0.000	.070	0.10
0	0.03	3.61	358	321	0.80E+05	.0085	.000	0.999	0.00	7.035	.000	0.000	0.000	0.000	.075	0.10
0	0.06	7.21	448	369	0.94E+05	.0082	.000	0.999	0.00	7.339	.000	0.000	0.000	0.000	.079	0.11
1	0.09	10.82	545	420	0.11E+06	.0079	.000	0.999	0.00	7.645	.000	0.000	0.000	-.001	.084	0.11
2	0.12	14.43	649	473	0.13E+06	.0075	.000	0.999	0.00	7.952	.000	0.000	0.000	-.001	.088	0.11
3	0.15	18.04	760	528	0.14E+06	.0072	.000	0.999	0.00	8.261	.000	0.000	0.000	-.001	.093	0.11
4	0.18	21.64	876	585	0.16E+06	.0069	.000	0.999	0.00	8.571	.000	0.000	0.000	-.001	.097	0.11
5	0.21	25.25	997	643	0.18E+06	.0065	.000	0.999	0.00	8.883	.000	0.000	0.000	-.002	.102	0.11
7	0.24	28.74	1118	701	0.20E+06	.0060	.000	0.999	0.00	9.185	.000	0.000	0.000	-.002	.106	0.11
19	0.50	28.74	1118	701	0.20E+06	.0060	.000	0.999	0.00	9.184	.000	0.000	0.000	-.004	.106	0.12
43	1.00	28.74	1120	702	0.20E+06	.0062	.000	0.999	0.00	9.147	.000	-.028	0.000	-.007	.106	0.12
48	1.10	28.74	1120	701	0.20E+06	.0062	.000	0.999	0.00	9.145	.000	-.031	0.000	-.008	.107	0.12
53	1.20	28.74	1120	702	0.20E+06	.0062	.000	0.999	0.01	9.142	.000	-.034	0.000	-.008	.107	0.12
92	2.00	28.74	1121	702	0.20E+06	.0063	.000	0.999	0.01	9.111	.000	-.056	0.000	-.014	.107	0.12
237	5.00	28.74	1124	703	0.20E+06	.0065	.000	0.999	0.01	9.022	.000	-.120	0.000	-.034	.108	0.12
480	10.00	28.74	1124	703	0.20E+06	.0067	.000	0.999	0.02	8.937	.000	-.186	0.000	-.067	.110	0.13
965	20.00	28.74	1119	701	0.20E+06	.0066	.000	0.999	0.02	8.866	.000	-.238	0.000	-.132	.112	0.13
1936	40.00	28.74	1104	695	0.20E+06	.0067	.000	0.999	0.03	8.857	.000	-.257	0.000	-.259	.114	0.14
2906	60.00	28.74	1078	685	0.19E+06	.0062	.000	0.999	0.04	8.944	.000	-.256	0.000	-.383	.116	0.14
3876	80.00	28.74	1054	675	0.19E+06	.0056	.000	0.999	0.04	9.043	.000	-.256	0.000	-.506	.118	0.15
4847	100.00	28.74	1032	666	0.19E+06	.0052	.000	0.999	0.05	9.149	.000	-.258	0.000	-.626	.119	0.15
6059	125.00	28.74	1009	657	0.18E+06	.0045	.000	0.999	0.06	9.270	.000	-.258	0.030	-.699	.121	0.15
7272	150.00	28.74	993	650	0.18E+06	.0042	.019	0.980	0.06	9.368	.000	-.258	0.060	-.724	.157	0.14
8485	175.00	28.74	984	645	0.18E+06	.0042	.018	0.981	0.07	9.430	.000	-.258	0.089	-.725	.177	0.15
9698	200.00	28.74	979	643	0.18E+06	.0041	.021	0.979	0.09	9.460	.000	-.258	0.117	-.714	.187	0.17
10426	215.00	28.74	977	642	0.18E+06	.0042	.022	0.978	0.09	9.501	.000	-.258	0.134	-.701	.188	0.18
10432	215.10	35.26	1178	732	0.21E+06	.0041	.049	0.950	0.10	9.417	.000	-.258	0.134	-.700	.308	0.31
10439	215.20	40.95	1337	809	0.23E+06	.0040	.061	0.939	0.10	9.327	.000	-.256	0.134	-.698	.347	0.40
10494	216.00	40.95	1306	798	0.23E+06	.0036	.052	0.948	0.12	9.322	.010	-.258	0.136	-.693	.260	0.38

TABLE A.18. FRAPCON-2 Prediction for 15 x 15 PWR with 8.8 kW/ft for 20 GWd/MTM, Ramp to 12.6 kW/ft, Constant Rod Average Power

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF GAP CONDUCTANCE CONTACT	FRACTION OF GAP CONDUCTANCE GAS	CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SHELL (%)	CLAD RADIUS (%) PERM	CLAD RADIUS (%) RECOVER	AXIAL (%) TOTAL
0	0.01	0.01	274	274	0.67E+05	.0086	.000	0.999	0.00	6.733	.000	0.000	0.000	0.000	.070	0.10
0	0.03	3.61	358	321	0.80E+05	.0085	.000	0.999	0.00	7.035	.000	0.000	0.000	0.000	.075	0.10
0	0.06	7.21	448	369	0.94E+05	.0082	.000	0.999	0.00	7.339	.000	0.000	0.000	0.000	.079	0.11
1	0.09	10.82	545	420	0.11E+06	.0079	.000	0.999	0.00	7.645	.000	0.000	0.000	-.001	.084	0.11
2	0.12	14.43	649	473	0.13E+06	.0075	.000	0.999	0.00	7.952	.000	0.000	0.000	-.001	.088	0.11
3	0.15	18.04	760	528	0.14E+06	.0072	.000	0.999	0.00	8.261	.000	0.000	0.000	-.001	.093	0.11
4	0.18	21.64	876	585	0.16E+06	.0069	.000	0.999	0.00	8.571	.000	0.000	0.000	-.001	.097	0.11
5	0.21	25.25	997	643	0.18E+06	.0065	.000	0.999	0.00	8.883	.000	0.000	0.000	-.002	.102	0.11
7	0.24	28.74	1118	701	0.20E+06	.0060	.000	0.999	0.00	9.185	.000	0.000	0.000	-.002	.106	0.11
19	0.50	28.74	1118	701	0.20E+06	.0060	.000	0.999	0.00	9.184	.000	0.000	0.000	-.004	.106	0.12
43	1.00	28.74	1120	702	0.20E+06	.0062	.000	0.999	0.00	9.147	.000	-.028	0.000	-.007	.106	0.12
48	1.10	28.74	1120	701	0.20E+06	.0062	.000	0.999	0.00	9.145	.000	-.031	0.000	-.008	.107	0.12
53	1.20	28.74	1120	702	0.20E+06	.0062	.000	0.999	0.01	9.142	.000	-.034	0.000	-.008	.107	0.12
92	2.00	28.74	1121	702	0.20E+06	.0063	.000	0.999	0.01	9.111	.000	-.056	0.000	-.014	.107	0.12
237	5.00	28.74	1124	703	0.20E+06	.0065	.000	0.999	0.01	9.022	.000	-.120	0.000	-.034	.108	0.12
480	10.00	28.74	1124	703	0.20E+06	.0067	.000	0.999	0.02	8.937	.000	-.186	0.000	-.067	.110	0.13
965	20.00	28.74	1119	701	0.20E+06	.0068	.000	0.999	0.02	8.866	.000	-.238	0.000	-.132	.112	0.13
1936	40.00	28.74	1104	695	0.20E+06	.0067	.000	0.999	0.03	8.857	.000	-.257	0.000	-.259	.114	0.14
2906	60.00	28.74	1078	685	0.19E+06	.0062	.000	0.999	0.04	8.944	.000	-.258	0.000	-.383	.116	0.14
3876	80.00	28.74	1054	675	0.19E+06	.0056	.000	0.999	0.04	9.043	.000	-.258	0.000	-.506	.118	0.15
4847	100.00	28.74	1032	666	0.19E+06	.0052	.000	0.999	0.05	9.149	.000	-.258	0.000	-.626	.119	0.15
6059	125.00	28.74	1009	657	0.18E+06	.0045	.000	0.999	0.06	9.270	.000	-.258	0.030	-.699	.121	0.15
7272	150.00	28.74	993	650	0.18E+06	.0042	.019	0.980	0.06	9.368	.000	-.258	0.060	-.724	.157	0.14
8485	175.00	28.74	984	645	0.18E+06	.0042	.018	0.981	0.07	9.430	.000	-.258	0.089	-.725	.177	0.15
9698	200.00	28.74	979	643	0.18E+06	.0041	.021	0.979	0.09	9.460	.000	-.258	0.117	-.714	.187	0.17
10911	225.00	28.74	975	641	0.18E+06	.0041	.024	0.975	0.10	9.507	.000	-.258	0.145	-.696	.192	0.19
12124	250.00	28.74	972	640	0.18E+06	.0041	.025	0.974	0.11	9.536	.001	-.258	0.173	-.665	.183	0.22
13337	275.00	28.74	972	640	0.18E+06	.0041	.024	0.975	0.12	9.552	.001	-.258	0.200	-.639	.183	0.24
14550	300.00	28.74	971	641	0.18E+06	.0036	.023	0.976	0.13	9.573	.001	-.258	0.228	-.614	.183	0.27
15763	325.00	28.74	970	641	0.18E+06	.0041	.023	0.976	0.14	9.595	.001	-.258	0.255	-.590	.183	0.29
16976	350.00	28.74	969	641	0.18E+06	.0041	.023	0.976	0.15	9.619	.001	-.258	0.282	-.565	.183	0.32
18189	375.00	28.74	969	641	0.18E+06	.0041	.023	0.976	0.17	9.643	.001	-.258	0.310	-.541	.183	0.34
19401	400.00	28.74	969	642	0.18E+06	.0040	.023	0.976	0.18	9.668	.002	-.258	0.337	-.516	.183	0.37
20614	425.00	28.74	970	642	0.18E+06	.0037	.023	0.976	0.19	9.693	.002	-.258	0.364	-.491	.183	0.39
20857	430.00	28.74	972	644	0.18E+06	.0041	.018	0.980	0.20	9.705	.002	-.258	0.369	-.487	.186	0.40
20863	430.10	35.26	1167	733	0.21E+06	.0040	.049	0.950	0.20	9.639	.002	-.258	0.370	-.486	.305	0.52
20870	430.20	40.95	1339	810	0.23E+06	.0039	.061	0.938	0.20	9.551	.002	-.258	0.370	-.485	.345	0.61
20925	431.00	40.95	1306	800	0.23E+06	.0035	.052	0.947	0.25	9.550	.002	-.258	0.371	-.480	.259	0.59

TABLE A.19. GAPCON-2 Prediction for 15 x 15 with 12.6 kW/ft to 20 GWd/MTM, P/A = 1.2

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (kW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF GAP CONDUCTANCE CONTACT	FRACTION OF GAP CONDUCTANCE GAS	CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD RADIUS (%) PERM	CLAD RADIUS (%) RECOVER	AXIAL (%) TOTAL
0	0.00	41.33	1650	1039	0.31E+06	.0033	.000	0.988	0.00	9.055	.000	0.000	0.000	0.000	.001	*
1978	29.60	41.33	1528	945	0.28E+06	.0021	.000	0.991	0.01	9.465	.001	-.004	0.000	0.000	.001	*
3956	59.10	41.33	1518	937	0.28E+06	.0019	.000	0.991	0.01	9.560	.003	-.004	0.000	0.000	.001	*
5934	88.70	41.33	1516	935	0.28E+06	.0020	.000	0.991	0.01	9.558	.004	-.004	0.000	0.000	.001	*
7912	118.30	41.33	1516	935	0.28E+06	.0019	.000	0.991	0.01	9.589	.006	-.004	0.000	0.000	.001	*
9890	147.80	41.33	1517	936	0.28E+06	.0019	.000	0.991	0.01	9.620	.008	-.004	0.000	0.000	.001	*
11868	177.40	41.33	1518	936	0.28E+06	.0019	.000	0.991	0.01	9.652	.011	-.004	0.000	0.000	.001	*
13846	206.90	41.33	1519	937	0.28E+06	.0019	.000	0.991	0.01	9.687	.013	-.004	0.000	0.000	.001	*
15824	236.50	41.33	1487	913	0.27E+06	.0016	.000	0.993	0.01	9.754	.016	-.004	0.001	0.000	.001	*
17804	266.10	41.33	1455	892	0.26E+06	.0013	.000	0.993	0.01	9.818	.018	-.004	0.002	0.000	.001	*
19780	295.60	41.33	1447	882	0.26E+06	.0012	.000	1.000	0.02	9.924	.020	-.004	0.003	0.000	.001	*

TABLE A.20. GAPCON-2 Prediction for 15 x 15 with 8.8 kW/ft for 20 GWd/MTM Ramp to 12.6 kW/ft, P/A = 1.2

BURN UP (MWD/MTU)	TIME (DAYS)	POWER (KW/M)	FUEL CENTER TEMP (C)	AVE FUEL TEMP (C)	AVE STORED ENERGY (J/KG)	RADIAL GAP WIDTH (CM)	FRACTION OF CONDUCTANCE GAP CONTACT	GAS	CUMMULATIVE ROD FISS GAS (%)	ROD INTERNAL GAS PRES (MPA)	XENON (MOLE FRAC)	FUEL DENS (%)	FUEL SWELL (%)	CLAD RADIUS (%) PERM	RECOVER	AXIAL (%) TOTAL
0	0.00	28.93	1230	847	0.25E+06	.0050	.000	0.992	0.00	5.226	.000	0.000	0.000	0.000	.001	-
1978	42.20	28.93	1142	779	0.23E+06	.0035	.000	0.997	0.00	5.628	.000	-.004	0.000	0.000	.001	-
3956	84.50	28.93	1135	772	0.22E+06	.0034	.000	0.997	0.00	5.669	.000	-.004	0.000	0.000	.001	-
5934	126.70	28.93	1133	772	0.22E+06	.0034	.000	0.997	0.00	5.691	.001	-.004	0.000	0.000	.001	-
7912	168.90	28.93	1133	772	0.22E+06	.0034	.000	0.997	0.00	5.706	.001	-.004	0.000	0.000	.001	-
9890	211.20	28.93	1133	772	0.22E+06	.0034	.000	0.997	0.00	5.721	.002	-.004	0.000	0.000	.001	-
11868	253.40	28.93	1134	773	0.22E+06	.0033	.000	0.997	0.00	5.738	.004	-.004	0.000	0.000	.001	-
13846	295.60	28.93	1134	773	0.22E+06	.0033	.000	0.997	0.01	5.756	.005	-.004	0.000	0.000	.001	-
15824	337.90	28.93	1113	756	0.22E+06	.0030	.000	0.997	0.01	5.816	.007	-.004	0.001	0.000	.001	-
17802	380.10	28.93	1092	740	0.21E+06	.0026	.000	1.000	0.01	5.902	.009	-.004	0.002	0.000	.001	-
19780	422.30	28.93	1447	882	0.26E+06	.0012	.000	1.005	0.01	9.892	.017	-.004	0.003	0.000	.001	-
19878	423.80	41.33	1446	882	0.26E+06	.0012	.000	1.000	0.01	9.895	.017	-.004	0.003	0.000	.001	-

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Computations of power history effects on the pre-loss-of-coolant accident conditions of generic pressurized water reactor and boiling water reactor fuel rods were preformed at Pacific Northwest Laboratory using the U. S. Nuclear Regulatory Commission code FRAPCON-2. Comparisons were made between cases where the fuel operated at a high power throughout life and those where the fuel was at a lower power for most of its burnup and ramped to the high power at 10,000 or 20,000 MWd/MTU burnup.

The PWR rod was calculated to have more cladding creepdown during the lower power cases, which resulted in slightly lower centerline temperatures. This result was insensitive to the method used to increase the power during the ramps. The calculations also indicate that the highest fuel centerline temperatures were reached at startup.

The BWR rod, however, demonstrated a substantial dependence on the power history. In this case, the constant high-power rod released considerable more fission gas than the lower power cases, which resulted in temperature differences of up to 350°C. The highest temperature was reached at end-of-life in the constant high-power case.

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