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ECAR-1804Results Of Reactor Physics Safety Analysis For Advanced Test Reactor (ATR) Cycle 151B

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Changing the World's Energy Future

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Idaho National Laboratory

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Title: Results of Reactor Physics Safety Analysis for Advanced Test Reactor Cycle 151B

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REVISION LOG

Rev.	Date	Affected Pages	Revision Description
0	2/9/12	All	Create
1	2/21/12	11	Corrected the Effective Point Power Limits for the NW lobe in Table 7

Title: Results of Reactor Physics Safety Analysis for Advanced Test Reactor Cycle 151B

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8. Objective/Purpose:

The Upgraded Final Safety Analysis Report (UFSAR) for the Advanced Test Reactor (ATR) requires that a reactor physics analysis be performed for each ATR cycle to assure that each ATR fuel element will operate within safety limits. The results reported in this Engineering Calculations and Analysis Report (ECAR) were obtained using the Upgraded Final Safety Analysis Report (UFSAR) PDQ X-Y model of the ATR core.

9. Conclusions/Recommendations:

Cycle 151B will run at a total core power of 102.5 MW for a nominal 53 days. Attached are the reactor physics data in support of the ATR Core Safety Assurance Program for Cycle 151B. The physics analysis contained herein was performed using a total core power of 102.5 MW with a fuel loading for 53 days. The results of the calculation show that none of the SAR/TSR limits will be violated during cycle 151B when in 2-PCP operation.

CONTENTS

APPENDIXES

SCOPE AND BRIEF DESCRIPTION

See above

DESIGN OR TECHNICAL PARAMETER INPUT AND SOURCES

1. Natural Phenomena Hazard (NPH) category and source (Performance Category per DOE-STD-1021 and/or Seismic Design Category per ANSI/ANS 2.26): N/A

2. Load scenarios and Acceptance Criteria: N/A

RESULTS OF LITERATURE SEARCHES AND OTHER BACKGROUND DATA

The analysis contained herein is performed routinely for each ATR cycle. The plan for performing and documenting the analysis is contained in the Technical Support Guide for the TSR Physics model.

ASSUMPTIONS

See Appendix A

COMPUTER CODE VALIDATION

Computer type:

UNIX Workstation (Castalia) See References 11 and 12 of Appendix A

A. Computer program name and revision: See Appendix A

B. Inputs: See Appendix A

C. Outputs: See Appendix A

D. Evidence of, or reference to, computer program validation: See Appendix A

E. Bases supporting application of the computer program to the specific physical problem: See Appendix A

DISCUSSION/ANALYSIS

See Appendix A

RECOMMENDATIONS

See Appendix A

REFERENCES

See Appendix A

Appendix A

Results of Reactor Physics Safety Analysis for Advanced Test Reactor (ATR) Cycle 151B

Introduction

The Upgraded Final Safety Analysis Report (UFSAR) for the Advanced Test Reactor (ATR) requires that a reactor physics analysis be performed to evaluate each ATR cycle. The results reported in this Engineering Calculations and Analysis Report (ECAR) were obtained using the Upgraded Final Safety Analysis Report (UFSAR) PDQ X-Y model of the ATR core. Reference 1 identifies a UFSAR commitment to use the UFSAR PDQ X-Y model for the required physics analysis. Nuclide densities for any recycled elements used in the fuel loading of this cycle were obtained from the UFSAR RECYCLE model.

Assumptions

Many of the fuel safety limits are expressed in terms of effective plate power (EPP). The EPP for a fuel element plate is the product of the effective point power and the average axial peaking factor. The effective point power is defined as the product of the total core power in megawatts (MW) and the maximum point-to-core-average power density ratio. The average axial peaking factor is obtained by normalizing the axial power profile such that the maximum axial peaking factor is equal to 1.0. The normalized power profile is integrated over the 48-inch active core height and the result is divided by the active core height (48 inches). The result is defined as the average axial peaking factor. The EPP values also include normalization using the ratio of the maximum lobe power to the actual calculated lobe power.

The PDQ analysis of Cycle 151B was run for 53 days (Ref. 5) using a nominal lobe power (MW) division of 19-14.5-23-23-23 (NW-NE-CR-SW-SE) for a total reactor power of 102.5 MW. Effective plate power (EPP) values have been computed using maximum lobe powers (MW) of 21-16-27-26-26 (NW-NE-CR-SW-SE) for normalization (Ref. 6). Loop experiments (Ref. 5) included in the PDQ model used for this calculation are shown in Table A1, along with lobe nominal, minimum, and maximum powers (Ref. 6).

Data

The Cycle 151B fuel charge consists of the following fuel elements:

11 New 7F elements	16 recycle 7F elements
4 New NB elements	0 recycle NB elements
0 New YA elements	0 recycle YA elements
0 New YA...M elements	9 recycle YA...M elements

The loading placement and previous irradiation history is shown in Table A2.

When the reflector adjacent to a lobe receives sufficient radiation exposure that the ligament A stress level exceeds a value of two standard deviations less than the failure stress, the safety limits for the effective point power and EPP for fuel elements adjacent to ligament A of that lobe must be reduced. The most recent update of the reflector lifetime analysis (as required by SAR 4.2.3.6.1) provides values for relating lobe exposure (integrated power) to limiting reflector stress levels. The exposure of the reflector adjacent to the SW and SE lobes has passed the level where the ligament A stress will exceed a value of two standard deviations less than the failure stress and it is expected that the exposure of the NW lobe will also exceed that level during this cycle. This ECAR documents the reduction in safety limits for the NW, SW, and SE lobes.

When the inspection of a new fuel element finds a reduced width in a coolant channel between fuel plates, the effective plate power limit for the plates adjacent to the narrow coolant channel must be reduced. The PDQ model used in this analysis tracks the power in 11 of the 19 fuel element plates. Those plates have numbers 1, 2, 3, 5, 8, 11, 15, 16, 17, 18, and 19. When an element has a reduced width in any coolant channel, the plate power limit will be restricted for any adjacent tracked plate or for the nearest tracked plate if there is no adjacent tracked plate. The fuel elements in the fuel loading for this cycle do not have any restrictions.

Analysis and Calculations

The calculation was performed using the PDQWS computer code on the castalia workstation. PDQWS results were processed using a suite of codes, including most importantly, ROSUB, PQMAP, GRAMS, TRNF, GOPPNP, LMFIS, POWCOR, and CRITOS. The cross-sections included in the input deck were generated using the codes: COMBINE, SCAMP, SCRABL, and RZPGM. Fuel inventory data for use in PDQWS is maintained by the codes: RECINV and RECYCLE.

The ATR PDQ model was run to represent the performance of the reactor during normal operation of Cycle 151B. The shim positions corresponding to this operation are shown in Table A5. The lobe powers and values of $K_{effective}$ for this run are shown in Table A6.

The ATR PDQ model was also run to represent the "worst-case" shim misalignment accident for each lobe. The shim positions corresponding to each misalignment configuration are shown in Table A7 and the resulting lobe powers and values of $K_{effective}$ are shown in Table A8.

Results and Conclusions

The PDQ analysis tracks the EPP in plate 19 and in ten of the remaining 18 plates of each of the 40 elements. The most limiting value in each lobe has been determined by evaluating the EPP in each of the 10 tracked inner fuel plates in each of the 8 elements of each lobe, and then factoring in any restrictions that have been placed on each fuel plate. The value that results from this analysis is often the maximum EPP value in the lobe, but occasionally a restriction causes a plate with less than the maximum EPP to be more limiting. The EPP value can be compared to the effective plate power limit and used in establishing acceptance criteria for the surveillance of the Lobe Power Calculation and Indication System (LPCIS) [TSR 3.6.1 (b)].

Table 1 shows the limits for the EPP as specified in ATR Technical Safety Requirements 3.6.1(a) (Table 3.6.1-1), and modified in Reference 13 for the inner plates along with the most limiting calculated EPP value for the inner plates in each lobe. Inner fuel plates are all plates except plate 19.

Table 1. Limiting Inner Plate EPP by Lobe

Lobe	Effective Plate Power Limit		Inner Plate Most Limiting EPP By Lobe				
	2 PCP	3 PCP	Pos.	Plate	Restricted to (%) of limit	Days	EPP
NW	340	330	F-32	5	100	0	253
NE	340	330	F-9	5	100	0	183
CR	340	330	F-20	5	100	3,10	228
SW	340	330	F-22	5	100	0	262
SE	340	330	F-19	5	100	0	258

The most limiting EPP in each lobe is less than the operating limit for 2 primary coolant pumps (PCP), so two-pump operation will be possible for this cycle.

Table 2 shows the most limiting inner plate EPP value in each quadrant rather than in each lobe. Center lobe elements have been combined into the adjacent corner lobe to make the four quadrants.

Table 2. Limiting Inner Plate EPP by Quadrant

Quadrant	Effective Plate Power Limit		Inner Plate Most Limiting EPP By Quadrant				
	2 PCP	3 PCP	Pos.	Plate	Restricted to (%) of limit	Days	EPP
NW	340	330	F-32	5	100	0	253
NE	340	330	F-9,F-10	5	100	0,3	183
SW	340	330	F-22	5	100	0	262
SE	340	330	F-19	5	100	0	258

Table 3 shows the limits for the EPP as specified in ATR Technical Safety Requirements 3.6.1(a) (Table 3.6.1-1), and modified in Reference 13 for plate 19 along with the most limiting calculated EPP value for plate 19 in each lobe.

Table 3. Limiting Plate 19 EPP by Lobe

Lobe	Effective Plate Power Limit		Plate 19 Most Limiting EPP By Lobe				
	2 PCP	3 PCP	Pos.	Plate	Restricted to (%) of limit	Days	EPP
NW	340	332	F-33	19	100	0	213
NE	340	332	F-8	19	100	0	138
CR	340	332	F-21	19	100	3	118
SW	340	332	F-23	19	100	0	221
SE	340	332	F-18	19	100	0	219

The plate 19 most limiting EPP values for each lobe are within the allowable TSR EPP limits for 2-PCP operation. Therefore, 2-PCP operation is still acceptable for this cycle.

The most limiting EPP values calculated for Cycle 151B elements at each time step are given in Table 4.

Table 4. Limiting EPP at Each Time Step

Plate Type	EPP Limit 2 PCP	Pos.	Plate	Restricted to (%) of limit	Days[a]	Cycle 151B Most Limiting EPP
19	340	23	19	100	0	221
Inner	340	22	5	100	0	262
19	340	18	19	100	3	200
Inner	340	20	5	100	3	228
19	340	18,23	19	100	10	195
Inner	340	20	5	100	10	228
19	340	23	19	100	17	193
Inner	340	20	5	100	17	222
19	340	18	19	100	24	188
Inner	340	19	5	100	24	222
19	340	18	19	100	31	185
Inner	340	19	5	100	31	224
19	340	18	19	100	38	179
Inner	340	19	5	100	38	220
19	340	23	19	100	45	174
Inner	340	19,22	5	100	45	217
19	340	23	19	100	52	168
Inner	340	22	5	100	52	217
19	340	23	19	100	53	166
Inner	340	22	5	100	53	212

a Data for the 0-day ganged outer shim case is not included

Exposure has exceeded the value for the limiting A-ligament stress level in the NW, SW, and SE lobe. Core positions F-34 through F-37 in the NW lobe, F-24 through F-27 in the SW lobe, and F-14 through F-17 in the SE lobe are adjacent to ligament A. Therefore the EPP limits in Tables 1-4 above are not applicable to these positions and reduced values as specified in ATR Technical Safety Requirements 3.6.1(a) (Table 3.6.1-1), and modified in Reference 13 must be used. The most limiting EPP values for these positions are given below along with the $<2\sigma$ limits.

Table 5. Limiting EPP for core positions for which Ligament A stress is $<2\sigma$ to cracking: F-14 through F-17 and F-24 through F-27

Lobe/Plate	**Effective Plate Power Limit**		**Cycle 151B Most Limiting EPP for** *Ligament A ($<2\sigma$) Positions By Lobe*				
	2 PCP	**3 PCP**	**EPP**	**Pos.**	**Plate**	**Days**	**Restricted to (%) of limit**
NW/Inner Plates	331	321	140	37	15	10	100
NW/Plate 19	291	266	111	34	19	10	100
SW/Inner Plates	331	321	180	24	15	24,31, 53	100
SW/Plate 19	291	266	164	24	19	3	100
SE/Inner Plates	331	321	185	17	15	53	100
SE/Plate 19	291	266	169	17	19	3	100

The elements in several positions of the fuel loading for this cycle, reach a fission density greater than $1.5x10^{21}$ during the cycle. For these elements, keeping the effective point powers less than the appropriate limits will prevent blistering of the fuel by ensuring that the maximum temperature will be at least 2σ less than 500°F (533°K) as required under UFSAR 4.2.1 as defined in Reference 4. Table 6 shows in which positions the elements have exceeded the $1.5 x10^{21}$ limit at each time step.

Table 6. Fuel Element Positions for which the fission density is greater than 1.5×10^{21}

Days	**Position Numbers**
0	3, 4, 5, 6, 7, 10
3	3, 4, 5, 6, 7, 10, 31
10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 30, 31, 40
17	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 20, 21, 30, 31, 40
24	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 20, 21, 30, 31, 40
31	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 15, 20, 21, 30, 31, 40
38	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 15, 20, 21, 30, 31, 40
45	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 15, 20, 21, 30, 31, 34, 40
52	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 15, 20, 21, 30, 31, 34, 40
53	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 15, 20, 21, 30, 31, 34, 40

Once an element exceeds 1.5 x 10^{21} fission density, its effective point power must not exceed the appropriate limit for its position as defined in Reference 4. Tables 7 and 8 identify the calculated effective point power for the most limiting element in each lobe for an inner plate and plate 19. Lobes with "NA" entries do not have any elements that exceed 1.5 x 10^{21} fission density during the cycle.

Table 7. Inner Plate Limiting Effective Point Power by lobe for fission density greater than 1.5 x 10^{21}

Lobe	Effective Point Power Limit		Cycle 151B Most Limiting Effective Point Power By Lobe				
	2 PCP	3 PCP	Pos.	Plate	Restricted to (%) of limit	Days	EPtP
NW	435	453	34	15	100	45,53	158
NE	446	465	F-9	5	100	10	190
CR	446	465	F-20	5	100	17	261
SW	435	453	N/A	N/A	N/A	N/A	N/A
SE	435	453	F-15	15	100	31	174

Table 8. Plate 19 Limiting Effective Point Power by lobe for fission density greater than 1.5 x 10^{21}

Lobe	Effective Point Power Limit		Cycle 151B Most Limiting Effective Point Power By Lobe				
	2 PCP	3 PCP	Pos.	Plate	Restricted to (%) of limit	Days	EPtP
NW	411	428	F-34	19	100	45,52,53	117
NE	411	428	F-8	19	100	10	155
CR	411	428	F-30	19	100	10	135
SW	411	428	N/A	N/A	N/A	N/A	N/A
SE	411	428	F-15	19	100	31	138

The worst-case LOBE powers equivalent to the TSR 3.6.1a, Table 3.6.1-1 effective plate power limits are shown in Table 9 on the next page. The worst-cases were found by simulating a lobe power unbalance accident using maximum shim unbalances in the PDQ model and the results are subsequently scaled to the limiting effective plate power.

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Table 9. Worst-case Lobe Powers at Effective Plate Power Limit

Lobe	Cycle Maximum LOBE Power (MW)	Maximum Unbalanced LOBE Power (MW)	Type of Position, Type of Plate	Limiting EPP at Maximum Unbalanced LOBE Power (MW)	Position	Plate	Restriction	Transient Effective Plate Power Limits and Overpower Ratios (MW)	Reference Lobe Power for Quadrant ΔT Setpoints (MW)
NW	21.0	33.10	All, inner plates	260	F-33	17	1.00	659/1.45 = 454	57.7*
			All, plate 19	254	F-33	19	1.00	659/1.45 = 454	59.1
			< 2σ, inner plates	233	F-35	17	1.00	641/1.45 = 442	62.7
			< 2σ, plate 19	186	F-34	19	1.00	490/1.37 = 357	63.5
NE	16.0	23.58	All, inner plates	166	F-9	5	1.00	659/1.45 = 454	64.4*
			All, plate 19	144	F-8	19	1.00	659/1.45 = 454	74.3
C	23.4	31.45	All, inner plates	212	F-20	5	1.00	659/1.45 = 454	67.3*
			All, plate 19	129	F-30	19	1.00	659/1.45 = 454	110.6
SW	26.0	39.93	All, inner plates	292	F-24	15	1.00	659/1.45 = 454	62.0
			All, plate 19	286	F-24	19	1.00	659/1.45 = 454	63.3
			< 2σ, inner plates	292	F-24	15	1.00	641/1.45 = 442	60.4
			< 2σ, plate 19	286	F-24	19	1.00	490/1.37 = 357	49.8*
SE	26.0	38.56	All, inner plates	282	F-17	15	1.00	659/1.45 = 454	62.0
			All, plate 19	278	F-17	19	1.00	659/1.45 = 454	62.9
			< 2σ, inner plates	282	F-17	15	1.00	641/1.45 = 442	60.4
			< 2σ, plate 19	278	F-17	19	1.00	490/1.37 = 357	49.5*

*indicates the minimum value for that lobe

The resulting worst-case lobe powers are used for establishing compliance with Technical Safety Requirement 3.1.1(a) (Table 3.1.1-1 SR#03) for the quadrant differential temperature set point. The effective plate power limits utilized the methods given in Reference 3. Each line in the table selects the element in a specific category that has the most limiting EPP once the individual plate restrictions have been considered. Values in the rightmost column are calculated by multiplying the values in columns 3, 8, and 9 and then dividing by the value in column 5. If the values in the rightmost column were smaller than the values in column 2, it would be necessary to reduce the requested maximum lobe powers accordingly. For this cycle no such adjustment will be necessary.

Table A9 lists the fuel element powers for each time step of the cycle. In order to find the maximum expected fuel element power for the cycle, the element powers in Table A9 are scaled to the lobe maximum power by multiplying by the ratio of the lobe maximum power divided by the actual lobe power. After examining all of the scaled fuel element powers for time steps beyond xenon equilibrium, we find that the maximum expected fuel element power during Cycle 151B is 3.964 MW in core position F-20.

The maximum calculated point-to-average power density ratio at a distance 90% from the edge of the fuel in plate 19 for any element is 2.74 in position F-23 for the time step 0.

The preliminary startup power division normalized to a total core power of 250 MW is: 45.8-33.4-65.0-55.0-50.8 (NW-NE-C-SW-SE).

The reactivity estimates and the fission density limits as given in UFSAR Section 4.2.1.2.3 are shown in Table 10.

Table 10. Reactivity Estimates and Fission Density Limits

	Reactivity Estimate[a]		Fission Density Limit (2.3×10^{21} fissions/cc)	
Lobe	**MWd**	**Time in Cycle[b] (Days)**	**MWd**	**Time in Cycle[c] (Days)**
NW	1222	64.3	1976	94.0
NE	680	46.8	1045	65.3
C	---	---	1433	61.2
SW	1762	76.6	2135	82.1
SE	1575	68.4	2374	91.3

a. The reactivity estimates were obtained using the XSPRJ method.
b. The Time in Cycle is based on the nominal power division of 19-14.5-23-23-23 (NW-NE-CR-SW-SE).
c. The Time in Cycle is based on the maximum power division of 21-16-23.4-26-26 (NW-NE-CR-SW-SE).

The results above show sufficient reactivity to sustain the requested lobe power for the cycle length of 53 days except for the NE quadrant. It is expected that the excess reactivity in the NW, SW, and SE quadrants will compensate for the shortage of reactivity in the NE quadrant. The results also show that the fission density limits should not be exceeded for a cycle length of 53 days in every lobe. The reactivity and fission density data are shown in Figures A1 and A2.

All of the elements in the fuel loading for Cycle 151B are expected to have further recycle potential after the nominal operation of Cycle 151B except for the following:

Pos.	Serial No.
10	YA522TM
11	XA393T

The methods used in this analysis are found in References 7 and 8.

Hardware and Software

Calculations were performed on the castalia workstation – cpu-property number 380414. The analysis codes along with their V&V tracking number are shown in Table 11. The V&V is documented in References 11 and 12.

Table 11. Computer Codes and V&V Tracking Numbers

Software Application Name	Version	Checksum Value	Enterprise Architecture Tracking Number
cmpr	1	1381	114931
critos	2	5760	114934
Fispk	-	50065	224935
goppl	02/99	37552	207598
grams	2	61942	114939
Lmfis	1	22139	114940
mxfis	-	4291	-
Pdq	1	61283	67621
powcor	1	4227	67618
pqmap	1	8421	114945
pqmapin	-	15808	-
pqxspl	1	16060	114947
recinv	1	11392	114949
recycle	1	56856	114950
rosub	2	29380	114952
rpcr2	-	55876	-
rzpgm	1	34117	114953
rzread	-	43442	114954
Trnf	1	2014	114957
updatr	1	25709	114958

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Table A1. Experimental Designations and Nominal Power Division for ATR Cycle 151B[5,6]

Lobe	Power	Loop Experiments
NW	19 (+2 / -4)	2E/NW-160 R#2E
N	-	1D/N-105 Var Flux/Temp Corr. R#0
NE	14.5 (+1.5 / -3.5)	AGR 3/4
W	-	1C/W-75 Med. Corr. R#0
C	23 (+0.4 / -3)	AFIP-6 Mk-II
E	-	7-Pin Flux Trap Irradiation Facility with LSA Cobalt in E-1 through E-7
SW	23 (+3 / -3)	2D/SW-218 Std BU
S	-	AGC-2
SE	23 (+3 / -3)	2B/SE-100 SST BU

Table A2. Summary of Fuel Load for Cycle 151B

Core	Serial	Content		Total	Irradiation History							
Pos.	No.	^{235}U	^{10}B	MWD	Cycle	Pos.	Cycle	Pos.	Cycle	Pos.	Cycle	Pos
1	YA539TM	762	0.061	2074	144A-1	15	145A-1	5				
2	XA682T	773	0.060	1626	141A-1	19	143A-1	38				
3	XA712T	754	0.057	1986	142B-1	22	149A-1	35				
4	YA507TM	704	0.037	2088	142B-1	37	149A-1	21				
5	XA713T	694	0.028	2214	142B-1	23	149A-1	31				
6	XA663T	697	0.031	2477	140A-1	12	145B-1	25				
7	YA426TM	704	0.036	1837	132A-1	39	148A-1	24				
8	XA119T	772	0.068	1614	131B-1	22	135C-1	32	137B-1	14		
9	YA485TM	774	0.070	1821	140B-1	7	144B-1	25				
10	YA522TM	735	0.047	2231	142B-1	15	144B-1	35				
11	XA393T	799	0.073	1756	137B-1	23	138B-1	27				
12	XA949T	1075	0.660									
13	XA952T	1075	0.660									
14	XA953T	1075	0.660									
15	XA874T	871	0.155	1094	148A-1	19						
16	XA933T	990	0.372	463	150A-1	22						
17	XA984T	1075	0.660									
18	XA955T	1075	0.660									
19	XA956T	1075	0.660									
20	XA878T	806	0.084	1821	148A-1	8	149B-1	6				
21	XA291T	808	0.086	1857	132C-1	7	135C-1	6	150A-1	9		
22	XA964T	1075	0.660									
23	XA965T	1075	0.660									
24	XA966T	1075	0.660									
25	XA918T	997	0.371	433	150A-1	18						
26	XA934T	1000	0.385	463	150A-1	28						
27	XA937T	995	0.386	463	150A-1	29						
28	XA968T	1075	0.660									
29	XA969T	1075	0.660									
30	XA282T	793	0.074	1769	131B-1	12	132C-1	24				
31	YA421TM	770	0.062	1715	131B-1	16	135B-1	24				
32	XA750TNB	1075	0.000									
33	XA751TNB	1075	0.000									
34	XA931T	904	0.188	965	149B-1	3						
35	YA469TM	961	0.321	433	150A-1	16						
36	YA456TM	962	0.324	433	150A-1	15						
37	YA520TM	956	0.309	463	150A-1	25						
38	XA752TNB	1075	0.000									
39	XA754TNB	1075	0.000									
40	XA375T	760	0.055	2343	138B-1	5	139B-1	5	141A-1	38		

Table A3. Plate Restrictions for Fuel Loaded in Cycle 151B[9,10]

Core Pos.	Serial No.	Restriction	Restricted Plates (of those represented in the PDQ model)
1	YA539TM		
2	XA682T		
3	XA712T		
4	YA507TM		
5	XA713T		
6	XA663T		
7	YA426TM		
8	XA119T		
9	YA485TM		
10	YA522TM		
11	XA393T		
12	XA949T		
13	XA952T		
14	XA953T		
15	XA874T		
16	XA933T		
17	XA984T		
18	XA955T		
19	XA956T		
20	XA878T		
21	XA291T		
22	XA964T		
23	XA965T		
24	XA966T		
25	XA918T		
26	XA934T		
27	XA937T		
28	XA968T		
29	XA969T		
30	XA282T		
31	YA421TM		
32	XA750TNB		
33	XA751TNB		
34	XA931T		
35	YA469TM		
36	YA456TM		
37	YA520TM		
38	XA752TNB		
39	XA754TNB		
40	XA375T		

Table A4. Capsule Facility Loading Used in ATR Cycle 151B Analysis[5]

Facility	Description	Reference
NEFT	AGR-3/4	SBG-05-11
CFT	AFIP-6 Mk II	HWG-03-11
E-1	LSA Cobalt	BJH-08-93
E-2	LSA Cobalt	BJH-08-93
E-3	LSA Cobalt	BJH-08-93
E-4	LSA Cobalt	BJH-08-93
E-5	LSA Cobalt	BJH-08-93
E-6	LSA Cobalt	BJH-08-93
E-7	LSA Cobalt	BJH-08-93
SFT	AGC-2	MED-01-11
A-1	IASFR	
A-2	IASFR	
A-3	IASFR	
A-4	HSA Cobalt	BJH-2-92
A-5	HSA Cobalt	BJH-2-92
A-6	HSA Cobalt	BJH-2-92
A-7	IASFR	
A-8	HSA Cobalt	BJH-2-92
A-9	SFROP	
A-10	AFC-3A	KEB-17-11
A-11	AFC-3B	KEB-17-11
A-12	SFROP	
A-13	LSFR	
A-14	EPRI –ZG-B	GWW-10-11
A-15	EPRI –ZG-C	GWW-10-11
A-16	EPRI –ZG-A	GWW-10-11
B-1	YSFR	
B-2	YSFR	
B-3	HSA Cobalt	BJH-73-88
B-4	HSA Cobalt	BJH-73-88
B-5	HSA Cobalt	BJH-73-88
B-6	HSA Cobalt	BJH-73-88
B-7	HSIS Hardware	Dwg. 600271

Table A4. Continued

Facility	Description	Reference
B-8	YSFR	
B-9	ISU-MANTRA-1	TLM-02-11
B-10	RERTR-13-2	GNH-09-11
B-11	RERTR-12-5	GNH-05-11
B-12	AGR-2	SBG-01-11, Rev.1
H-1	HSA Cobalt	TMS-06-08
H-2	HSA Cobalt	TMS-06-08
H-3	N-16 MONITOR	
H-4	HSA Cobalt	TMS-06-08
H-5	LSA Cobalt	RAK-02-02
H-6	HSA Cobalt	TMS-06-08
H-7	HSA Cobalt	TMS-06-08
H-8	HSA Cobalt	TMS-06-08
H-9	HSA Cobalt	TMS-06-08
H-10	HSA Cobalt	TMS-06-08
H-11	N-16 MONITOR	
H-12	HSA Cobalt	TMS-06-08
H-13	HSA Cobalt	TMS-06-08
H-14	HSA Cobalt	TMS-06-08
H-15	HSA Cobalt	TMS-06-08
H-16	HSA Cobalt	TMS-06-08
I-1 thru I-20	Beryllium Filler	
I-21	Beryllium Filler	
I-22	UCSB-2	TLM-01-11
I-23	Aluminum Filler	
I-24	Aluminum Filler	

Table A5. Summary of ATR Shim Positions for ATR Cycle 151B

Time At Power (Days)	NW LOBE Outer Shims (Deg.)	NW LOBE Neck Shims Inserted	NE LOBE Outer Shims (Deg.)	NE LOBE Neck Shims Inserted	SW LOBE Outer Shims (Deg.)	SW LOBE Neck Shims Inserted	SE LOBE Outer Shims (Deg.)	SE LOBE Neck Shims Inserted
0	34.4	1 2 3 4 5 6	34.4	1 2 3 4 5 6	34.4	1 2 3 5 6	34.4	1 2 3 5 6
0	20.9	1 2 3 4 5 6	24.8	1 2 3 4 5 6	40.1	1 2 3 5 6	51.2	1 2 3 5 6
3	79.3	1 2 3 4 5 6	85.4	1 2 3 4 5 6	79.3	1 2 3 5 6	85.4	1 2 3 5
10	85.4	1 2 3 4 5 6	85.4	1 2 3 4 5 6	79.3	1 2 3 5 6	85.4	1 2 3
17	85.4	1 2 3 4 5	85.4	1 2 3 4 5	79.3	1 2 3 5 6	85.4	1 2
24	85.4	1 2 3 4	85.4	1 2 3 4	85.4	1 2 3 5 6	85.4	1
31	85.4	1 2 3	85.4	1 2 3	85.4	1 2 3 5	85.4	
38	85.4	1 2	85.4	1 2	85.4	1 2 3	89.8	
45	85.4		85.4	1	85.4	1 2	95.2	
52	100.1		89.8		89.8		104.2	
53	104.2		95.2		95.2		111.7	

Table A6. Summary of ATR Core Power and Calculated $K_{effective}$ for ATR Cycle 151B

Time at Power (Days)	Total Core Power (MW)	Lobe Powers (MW) NW	NE	CR	SW	SE	$K_{effective}$
0	102.5	18.8	13.7	26.6	22.6	20.8	0.9882
0	102.5	17.1	12.9	26.3	23.0	23.3	0.9913
3	102.5	18.2	14.3	22.5	23.8	23.7	0.9947
10	102.5	18.2	14.1	22.2	23.8	24.3	0.9935
17	102.5	18.2	14.2	22.2	23.4	24.4	0.9944
24	102.5	18.1	14.2	22.2	24.0	24.1	0.9972
31	102.5	18.0	14.2	22.5	24.0	23.9	0.9986
38	102.5	17.9	14.1	22.5	24.0	24.1	0.9988
45	102.5	18.1	13.9	23.1	23.5	23.9	1.0010
52	102.5	18.6	13.6	23.1	23.5	23.7	1.0059
53	102.5	18.3	13.6	22.7	23.8	24.1	1.0088

Table A7. Summary of ATR Shim Positions for ATR Cycle 151B Worst Case Calculations

	NW LOBE		NE LOBE		SW LOBE		SE LOBE	
Lobe	**(Deg.)**	**Inserted**	**(Deg.)**	**Inserted**	**(Deg.)**	**Inserted**	**(Deg.)**	**Inserted**
NW	153.9	1 1 1 1 1 1	34.4	1 1 1 1 1 1	34.4	1 1 1 0 1 1	0.0	1 1 1 0 1 1
NE	34.4	1 1 1 1 1 1	153.9	1 1 1 1 1 1	0.0	1 1 1 0 1 1	34.4	1 1 1 0 1 0
CR	0.0	0 0 0 0 0 0	0.0	0 0 0 0 0 0	0.0	0 0 0 0 0 0	0.0	0 0 0 0 0 0
SW	34.4	1 1 1 1 1 1	0.0	1 1 1 1 1 1	153.9	1 1 1 0 1 1	34.4	1 1 1 0 1 1
SE	0.0	1 1 1 1 1 1	34.4	1 1 1 1 1 1	34.4	1 1 1 0 1 1	153.9	1 1 1 0 1 1

Table A8. Summary of ATR Core Power and Calculated $K_{effective}$ for Worst-Case Calculations

	Total Core Power	Lobe Powers (MW)					
Lobe	**(MW)**	**NW**	**NE**	**CR**	**SW**	**SE**	**$K_{effective}$**
NW	102.5	33.0997	12.1239	24.0525	19.0657	14.1582	1.009834
NE	102.5	17.3728	23.5826	25.1325	17.0936	19.3185	0.998541
CR	102.5	18.7937	14.4630	31.4512	19.4636	18.3285	1.037889
SW	102.5	14.7678	8.7318	22.7126	39.9322	16.3557	1.026597
SE	102.5	11.7404	11.4535	22.9797	17.7675	38.5588	1.022781

Table A9. Summary of Fuel Element Powers for ATR Cycle 151B

Time At Power (Days)	Total Core Power (MW)	Power (MW) For Fuel Element In Core Positions 1-10									
		1	2	3	4	5	6	7	8	9	10
0	102.5	3.0	2.5	2.1	1.2	0.9	0.9	1.3	2.2	2.6	3.0
0	102.5	2.9	2.4	1.9	1.1	0.8	0.8	1.2	2.1	2.5	3.0
3	102.5	2.5	2.2	2.0	1.5	1.3	1.3	1.6	2.2	2.3	2.6
10	102.5	2.4	2.1	2.0	1.5	1.3	1.3	1.5	2.2	2.2	2.5
17	102.5	2.4	2.2	2.0	1.5	1.3	1.3	1.5	2.2	2.3	2.5
24	102.5	2.4	2.3	2.0	1.4	1.2	1.3	1.5	2.2	2.4	2.5
31	102.5	2.5	2.3	1.9	1.4	1.2	1.2	1.5	2.1	2.4	2.6
38	102.5	2.5	2.3	1.9	1.4	1.2	1.2	1.5	2.1	2.4	2.6
45	102.5	2.6	2.4	1.9	1.4	1.2	1.2	1.4	2.1	2.4	2.7
52	102.5	2.7	2.3	1.9	1.3	1.1	1.2	1.4	2.0	2.4	2.7
53	102.5	2.6	2.3	1.9	1.3	1.2	1.2	1.4	2.0	2.3	2.6

Time At Power (Days)	Total Core Power (MW)	Power (MW) For Fuel Element In Core Positions 11-20									
		11	12	13	14	15	16	17	18	19	20
0	102.5	3.3	3.2	2.9	2.2	1.7	1.8	2.3	3.2	3.6	3.6
0	102.5	3.4	3.4	3.2	2.6	2.0	2.2	2.7	3.5	3.7	3.7
3	102.5	2.9	3.0	3.1	2.8	2.5	2.7	2.9	3.4	3.3	3.2
10	102.5	2.9	3.1	3.1	2.8	2.6	2.7	3.0	3.4	3.5	3.2
17	102.5	3.0	3.2	3.2	2.9	2.6	2.7	3.0	3.5	3.5	3.2
24	102.5	3.0	3.1	3.1	2.8	2.5	2.7	3.0	3.4	3.5	3.2
31	102.5	3.1	3.2	3.1	2.8	2.4	2.6	2.9	3.4	3.5	3.3
38	102.5	3.0	3.1	3.1	2.8	2.5	2.7	3.0	3.4	3.5	3.2
45	102.5	3.0	3.1	3.1	2.8	2.5	2.7	3.0	3.4	3.4	3.2
52	102.5	2.9	3.0	3.0	2.8	2.5	2.7	3.0	3.3	3.3	3.1
53	102.5	2.9	3.0	3.0	2.9	2.6	2.8	3.1	3.3	3.3	3.1

Table A9. Continued

Time At Power (Days)	Total Core Power (MW)	Power (MW) For Fuel Element In Core Positions 21-30									
		21	22	23	24	25	26	27	28	29	30
0	102.5	3.7	3.7	3.4	2.5	2.0	1.9	2.4	3.2	3.6	3.5
0	102.5	3.7	3.7	3.4	2.6	2.0	2.0	2.4	3.2	3.5	3.4
3	102.5	3.2	3.2	3.4	2.9	2.6	2.6	2.8	3.1	3.1	2.9
10	102.5	3.1	3.2	3.4	2.9	2.7	2.6	2.8	3.1	3.1	2.9
17	102.5	3.1	3.2	3.3	2.9	2.6	2.6	2.7	3.1	3.0	2.8
24	102.5	3.0	3.2	3.4	3.0	2.7	2.7	2.8	3.1	3.0	2.8
31	102.5	3.0	3.2	3.4	3.0	2.7	2.7	2.8	3.1	3.1	2.8
38	102.5	3.0	3.3	3.4	3.0	2.7	2.7	2.8	3.1	3.2	2.8
45	102.5	3.1	3.3	3.3	2.9	2.6	2.6	2.7	3.1	3.2	2.9
52	102.5	3.2	3.3	3.3	2.9	2.6	2.6	2.7	3.1	3.2	3.0
53	102.5	3.1	3.2	3.3	2.9	2.7	2.7	2.7	3.1	3.2	2.9

Time At Power (Days)	Total Core Power (MW)	Power (MW) For Fuel Element In Core Positions 31-40									
		31	32	33	34	35	36	37	38	39	40
0	102.5	3.3	3.6	3.0	1.7	1.3	1.3	1.6	2.8	3.4	3.2
0	102.5	3.2	3.4	2.8	1.5	1.1	1.1	1.4	2.6	3.2	3.0
3	102.5	2.7	3.0	2.8	1.9	1.6	1.6	1.8	2.6	2.8	2.6
10	102.5	2.7	2.9	2.7	2.0	1.7	1.7	1.9	2.5	2.7	2.5
17	102.5	2.7	2.9	2.7	2.0	1.7	1.7	1.9	2.5	2.8	2.5
24	102.5	2.6	3.0	2.7	1.9	1.7	1.7	1.8	2.5	2.9	2.5
31	102.5	2.7	3.0	2.6	1.9	1.7	1.6	1.8	2.5	2.9	2.5
38	102.5	2.7	3.0	2.6	1.9	1.6	1.6	1.8	2.4	2.9	2.6
45	102.5	2.9	3.1	2.6	1.9	1.6	1.6	1.8	2.5	3.0	2.8
52	102.5	2.8	3.1	2.7	2.0	1.8	1.8	1.9	2.5	3.0	2.7
53	102.5	2.8	3.0	2.6	2.0	1.8	1.8	1.9	2.4	2.9	2.7

Title: Results of Reactor Physics Safety Analysis for Advanced Test Reactor Cycle 151B

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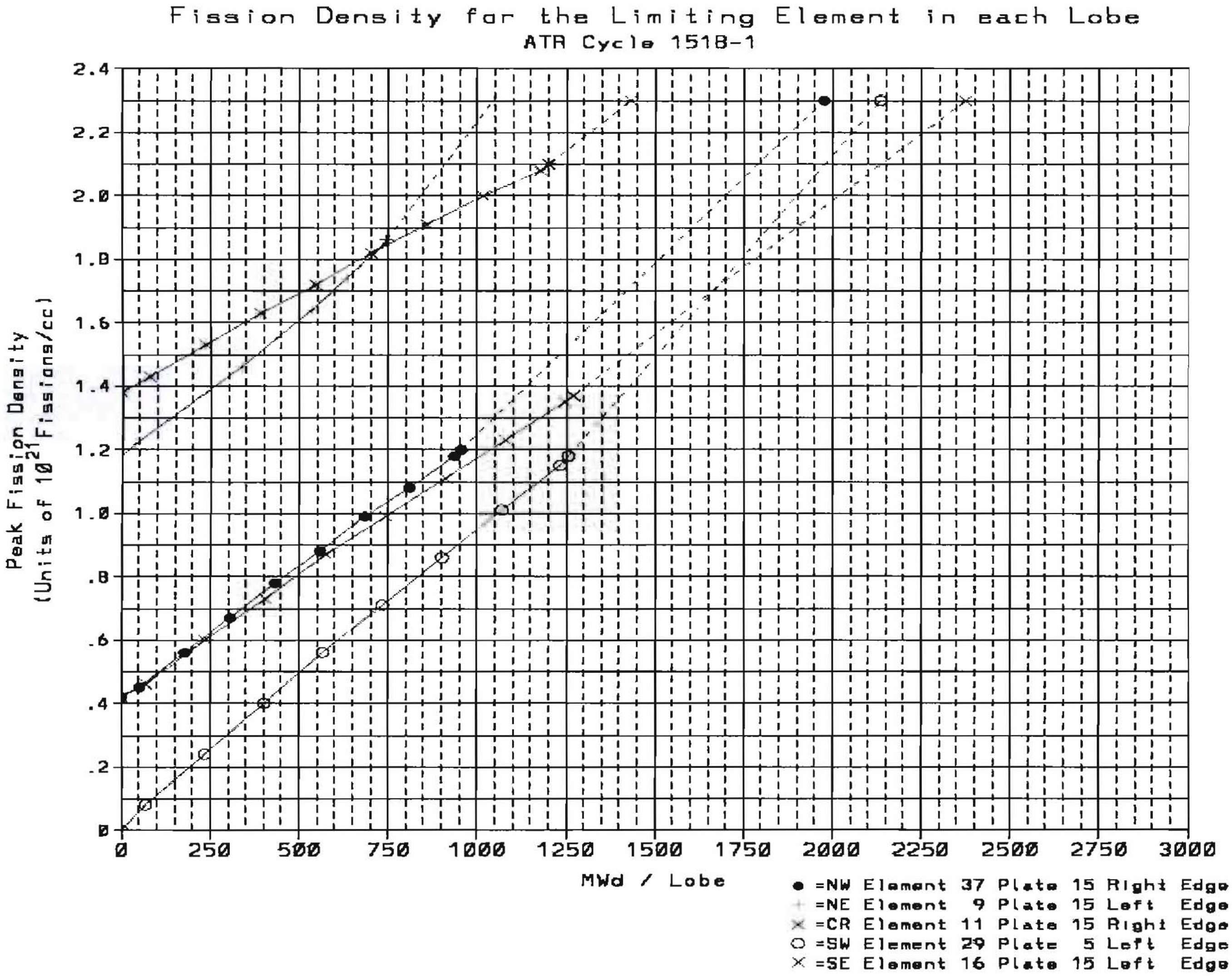

Title: Results of Reactor Physics Safety Analysis for Advanced Test Reactor Cycle 151B

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