ENGINEERING CALCULATIONS AND ANALYSIS REPORT

Title: RESULTS OF REACTOR PHYSICS SAFETY ANALYSIS FOR ADVANCED TEST REACTOR (ATR) CYCLE 150A

ECAR No.: 1608 ECAR Rev. No.: 0 Project File No.:

1. Index Codes			
	Building/Type:	SSC ID:	Site Area:
2. Quality Level and Determination No.:			
	QL = 1; Determination No. = RTC-000088		

3. 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.

4. Conclusions/Recommendations:

Cycle 150A will run at a total core power of 153 MW for a nominal 1 day and at 141 MW for the remaining days of the nominal 13 day cycle. Attached are the reactor physics data in support of the ATR Core Safety Assurance Program for Cycle 150A. The physics analysis contained herein was performed using a total core power of 155 MW for a nominal 1 day and at 141 MW for the remaining days using a nominal 13 day fuel loading. The results of the calculation show that none of the SAR/TSR limits will be violated during cycle 150A when in 3-PCP operation.

5. Review (R) and Approval (A) and Acceptance (Ac)[1]:

		Typed Name/Organization	Signature or eCR No.[2]
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1 Review and Approval are required. See LWP-10200 for definitions and responsibilities.

2 Electronic Change Request (eCR) numbers in lieu of signatures on this page indicate electronic final review, approval and acceptance by the listed individuals.

3 If required, per LWP-10200.

4 Required if the ECAR contains safety software validation.

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APPENDIXES

Appendix A – Results of Reactor Physics Safety Analysis for Advanced Test Reactor (ATR) Cycle 150A

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

a. Computer type: UNIX Workstation (Castalia) See References 11 and 12 of Appendix A
b. Computer program name and revision: See Appendix A
c. Inputs (may refer to an appendix): See Appendix A
d. Outputs (may refer to an appendix): See Appendix A
e. Evidence of, or reference to, computer program validation: See Appendix A
f. Bases supporting application of the computer program to the specific physical problem: See Appendix A

DISCUSSION/ANALYSIS

See Appendix A

RECOMMENDATIONS

See Appendix A

PE STAMP

N/A

REFERENCES

See Appendix A

APPENDIXES

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Appendix A - Results of Reactor Physics Safety Analysis for Advanced Test Reactor (ATR) Cycle 150A

1. 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.

2. 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 150A was run for 1 day (Ref. 5) using a nominal lobe power (MW) division of 18-18-34-45-40 (NW-NE-CR-SW-SE) for a total reactor power of 155 MW, and then was run for an additional 12 days using a nominal lobe power (MW) division of 18-18-31-39-35 (NW-NE-CR-SW-SE). Effective plate power (EPP) values have been computed using maximum lobe powers (MW) of 21-19.5-41-55-48 (NW-NE-CR-SW-SE) for the first day and requested maximum lobe powers (MW) of 21-19.5-37-47-43 (NW-NE-CR-SW-SE) for the remaining 12 days 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).

3. Data

The Cycle 150A fuel charge consists of the following fuel elements:

5 New 7F elements	24 recycle 7F elements
0 New NB elements	1 recycle NB elements
0 New YA elements	0 recycle YA elements
8 New YA...M elements	2 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. This ECAR documents the reduction in safety limits in those two 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.

4. 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 150A. 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.

5. 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) 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	417	443	F-32	5	100	1 hi	209
NE	417	443	F-9	5	100	1 hi	227
CR	417	443	F-20	5	100	1 hi	364
SW	417	443	F-22	5	100	1 hi	422
SE	417	443	F-18	15	100	0	378

In the "Days" column of Tables 1-7, "1 hi" refers to the point in time at the end of the first day when the power is still at the initial power split. Similarly, "1 lo" refers to the point in time at the end of the first day when the power split has changed to that used for the remaining 12 days of the run. The most limiting EPP in each lobe is less than the operating limit for 3 primary coolant pumps (PCP), except for the SW lobe, which is above the limit for 2 PCP operations. Therefore, three-pump operation will be required 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	417	443	F-31	5	100	1 hi	264
NE	417	443	F-10	5	100	1 hi	279
SW	417	443	F-22	5	100	1 hi	422
SE	417	443	F-18	15	100	0	378

Table 3 shows the limits for the EPP as specified in ATR Technical Safety Requirements 3.6.1(a) (Table 3.6.1-1) 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	417	445	F-33	19	100	1 hi	144
NE	417	445	F-8	19	100	1 hi	181
CR	417	445	F-21	19	100	1 hi	212
SW	417	445	F-23	19	100	1 hi	391
SE	417	445	F-18	19	100	1 hi	362

The plate 19 most limiting EPP values for each lobe are within the allowable TSR EPP limits for 3-PCP operation. Therefore, 3-PCP operation is acceptable for this cycle.

The most limiting EPP values calculated for Cycle 150A elements at each time step are given in Table 4.

Table 4. Limiting EPP at Each Time Step

Plate Type	EPP Limit 3 PCP	Pos.	Plate	Restricted to (%) of limit	Days[a]	Cycle 150A Most Limiting EPP
19	445	23	19	100	0	382
Inner	443	24	15	100	0	411
19	445	23	19	100	1 hi	391
Inner	443	22	5	100	1 hi	422
19	445	23	19	100	1 lo	338
Inner	443	22	5	100	1 lo	370
19	445	23	19	100	3	336
Inner	443	22	5	100	3	371
19	445	23	19	100	10	322
Inner	443	22	5	100	10	359
19	445	23	19	100	13	316
Inner	443	22	5	100	13	352

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

Exposure exceeded the value for the limiting A-ligament stress level in the SW and SE lobe during cycle 147A. Core positions 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) must be used. The most limiting EPP values for these positions are given below along with the $<2\sigma$ limits. The values for most limiting EPP values for the SW and SE are not calculated due to the absence of fuel in the YAM elements in those positions.

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

Lobe/Plate	Effective Plate Power Limit		Cycle 150A Most Limiting EPP for Ligament A (<2σ) Positions By Lobe				
	2 PCP	3 PCP	EPP	Pos.	Plate	Days	Restricted to (%) of limit
SW/Inner Plates	406	431	414	24	17	1 hi	100
SW/Plate 19	358	357	N/A	N/A	19	N/A	100
SE/Inner Plates	406	431	368	17	17	1 hi	100
SE/Plate 19	358	357	N/A	N/A	19	N/A	100

The elements in several positions of the fuel loading for this cycle, reach a fission density greater than 1.5×10^{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 1.5×10^{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	1, 10, 11, 20, 21, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40
1dh	1, 10, 11, 20, 21, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40
1dl	1, 10, 11, 20, 21, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40
3	1, 10, 11, 20, 21, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40
10	1, 10, 11, 20, 21, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40
13	1, 10, 11, 20, 21, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40

Once an element exceeds 1.5×10^{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 1.5×10^{21} fission density during the cycle.

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

Lobe	Effective Point Power Limit		Cycle 150A Most Limiting Effective Point Power By Lobe				
	2 PCP	3 PCP	Pos.	Plate	Restricted to (%) of limit	Days	EPtP
NW	446	465	F-32	5	100	1 hi	258
NE	446	465	N/A	N/A	100	N/A	N/A
CR	446	465	F-21	5	100	1 hi	441
SW	435	453	N/A	N/A	100	N/A	N/A
SE	435	453	N/A	N/A	100	N/A	N/A

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

Lobe	Effective Point Power Limit		Cycle 150A Most Limiting Effective Point Power By Lobe				
	2 PCP	3 PCP	Pos.	Plate	Restricted to (%) of limit	Days	EPtP
NW	411	428	F-33	19	100	1 hi	164
NE	411	428	N/A	19	100	N/A	N/A
CR	411	428	F-21	19	100	1 hi	258
SW	411	428	N/A	19	100	N/A	N/A
SE	411	428	N/A	19	100	N/A	N/A

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	**29.3**	All, inner plates	210	F-32	5	1.00	709/1.45 =	488	**68.0***
			All, plate 19	143	F-38	19	1.00	712/1.45 =	491	**100.6**
NE	19.5	**33.88**	All, inner plates	255	F-9	5	1.00	709/1.45 =	488	**64.8***
			All, plate 19	230	F-8	19	1.00	712/1.45 =	491	**72.3**
C	41.0	**45.44**	All, inner plates	313	F-21	5	1.00	709/1.45 =	488	**70.8***
			All, plate 19	198	F-21	19	1.00	712/1.45 =	491	**112.6**
SW	55.0	**63.35**	All, inner plates	532	F-25	17	1.00	709/1.45 =	488	**58.1**
			All, plate 19	427	F-23	19	1.00	712/1.45 =	491	**72.8**
			< 2 sigma, inner plates	532	F-25	17	1.00	690/1.45 =	475	**56.5***
			< 2 sigma, plate 19	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SE	48.0	**58.33**	All, inner plates	490	F-16	17	1.00	709/1.45 =	488	**58.0**
			All, plate 19	406	F-18	19	1.00	712/1.45 =	491	**70.5**
			< 2 sigma, inner plates	490	F-16	17	1.00	690/1.45 =	475	**56.5***
			< 2 sigma, plate 19	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* indicates minimum value for the 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 150A is 6.613 MW in core position F-22.

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 2.96 in position F-23 for the time step 1hi.

The preliminary startup power division normalized to a total core power of 250 MW is: 29.8-31.8-50.9-72.0-65.6(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	214	11.9	402	19.1
NE	621	34.5	1230	63.0
C	---	---	1031	25.1
SW	1297	33.2	2442	44.4
SE	1050	30.0	1708	35.5

a. The reactivity estimates were obtained using the XSPRJ method.
b. The Time in Cycle is based on the nominal power division of 18-18-31-39-35 (NW-NE-CR-SW-SE).
c. The Time in Cycle is based on the maximum power division of 21-19.5-41-55/-48 (NW-NE-CR-SW-SE).

The results above show sufficient reactivity to sustain the requested lobe power for the cycle length of 13 days except for the NW Lobe. PDQ typically underestimates the reactivity in the NW lobe by approximately 0.50$, so this should not be a problem. The results also show that the fission density limits should not be exceeded for a cycle length of 13 days. The reactivity and fission density data are shown in Figures A1 and A2.

All of the elements in the fuel loading for Cycle 150A are expected to have further recycle potential after the nominal operation of Cycle 150A except for the following:

Pos.	Serial No.
32	XA801T
33	XA377T

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

6. 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

7. References

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4. Davis, C. B., Compliance With ATR SAR Commitment on fuel Design Temperatures, TEV-556, October 29, 2009
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12. Roth, P. A., Verification and Validation of ATR Physics Analysis Software, rzpgm and rzread, on Workstation Castalia, ECAR-593, April 29, 2009.

Table A1. Experimental Designations and Nominal Power Division for ATR Cycle 150A[5,6]

Lobe	Power	Loop Experiments
NW	18 (+3 / -3)	2E-NW-161 PV-14 R#0
N	-	1D-N-105 Var Flux/Temp Corr. R#0
NE	18 (+1.5 / -2)	MICE Facility with 2 MRW B/Us and Structural 8A & 8B
W	-	1C/W-75 Med. Corr. R#0
C	34/31 (+2/+5 / -5/-2)	1 LSA Cobalt/6 Aluminum Fillers CFT 1 - 7
E	-	LSA Cobalt EFT 1 - 7
SW	45/39 (+10/+8 / -10/-8)	2D-SW-186 P-TP-390 Tr#1 R#0
S	-	LSA Cobalt SFT 1 - 7
SE	40/35 (+8/+8 / -8/-8)	2B-SE-100 SS BU R#1

Table A2. Summary of Fuel Load for Cycle 150A

Core Pos.	Serial No.	Content ^{235}U	^{10}B	Total MWD	Irradiation History Cycle	Pos.	Cycle	Pos.	Cycle	Pos.
1	XA709T	716	0.033	2295	142A-1	18	144B-1	26		
2	XA570T	859	0.127	1614	137B-1	26	139A-1	5		
3	XA635T	854	0.133	1289	139A-1	12				
4	XA821T	850	0.132	1191	144B-1	22				
5	XA719T	827	0.119	1315	143A-1	22				
6	XA651T	843	0.121	1766	139A-1	7	140A-1	5		
7	XA604TNB	852	0	1766	139A-1	6	140A-1	6		
8	XA840T	855	0.122	1300	145A-1	28				
9	XA291T	858	0.134	1635	132C-1	7	135C-1	6		
10	XA708T	722	0.042	1969	142B-1	3	143B-1	38		
11	XA700T	736	0.043	2006	142B-1	13	146B-1	8		
12	XA859T	961	0.294	904	146B-1	36				
13	XA879T	894	0.189	856	148A-1	32				
14	YA438TM	1023	0.517							
15	YA456TM	1023	0.517							
16	YA469TM	1023	0.517							
17	YA481TM	1023	0.517							
18	XA918T	1075	0.66							
19	XA226T	914	0.202	927	148B-1	3				
20	XA802T	739	0.044	1988	144A-1	24	145A-1	38		
21	XA691T	742	0.047	1892	142A-1	38	144A-1	33		
22	XA933T	1075	0.66							
23	XA936T	1075	0.66							
24	YA490TM	1023	0.517							
25	YA520TM	1023	0.517							
26	YA527TM	1023	0.517							
27	YA529TM	1023	0.517							
28	XA934T	1075	0.66							
29	XA937T	1075	0.66							
30	XA791T	733	0.041	2076	144A-1	14	145A-1	33		
31	XA706T	729	0.043	2261	142A-1	12	147A-1	36		
32	XA801T	704	0.038	1808	144A-1	2	145B-1	32		
33	XA377T	657	0.02	2792	138B-1	7	139B-1	27	140B-1	11
34	YA465TM	649	0.02	2368	139A-1	24	148B-1	30		
35	XA675T	627	0.017	2947	140B-1	12	142A-1	36	146B-1	30
36	XA580T	618	0.013	2680	138A-1	18	146A-1	30		
37	YA549TM	641	0.019	2500	145B-1	16	146B-1	21		
38	XA730T	686	0.03	2378	143A-1	19	147A-1	16		
39	XA711T	701	0.033	1969	142B-1	8	143B-1	39		
40	XA804T	719	0.039	1988	144A-1	27	145A-1	39		

Title: RESULTS OF REACTOR PHYSICS SAFETY ANALYSIS FOR ADVANCED TEST REACTOR (ATR) CYCLE 150A

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Table A3. Plate Restrictions for Fuel Loaded in Cycle 150A[9,10]

Core Pos.	Serial No.	Restriction	Restricted Plates (of those represented in the PDQ model)
1	XA709T		
2	XA570T		
3	XA635T		
4	XA821T		
5	XA719T		
6	XA651T		
7	XA604TNB		
8	XA840T		
9	XA291T		
10	XA708T		
11	XA700T		
12	XA859T		
13	XA879T		
14	YA438TM		
15	YA456TM		
16	YA469TM		
17	YA481TM		
18	XA918T		
19	XA226T		
20	XA802T		
21	XA691T		
22	XA933T		
23	XA936T		
24	YA490TM		
25	YA520TM		
26	YA527TM		
27	YA529TM		
28	XA934T		
29	XA937T		
30	XA791T		
31	XA706T		
32	XA801T		
33	XA377T		
34	YA465TM		
35	XA675T		
36	XA580T		
37	YA549TM		
38	XA730T		
39	XA711T		
40	XA804T		

Table A4. Capsule Facility Loading Used in ATR Cycle 150A Analysis[5]

Facility	Description	Reference
EFT-1	LSA Cobalt	BJH-08-93
EFT-2	LSA Cobalt	BJH-08-93
EFT-3	LAS Cobalt	BJH-08-93
EFT-4	LSA Cobalt	BJH-08-93
EFT-5	LSA Cobalt	BJH-08-93
EFT-6	LSA Cobalt	BJH-08-93
EFT-7	LSA Cobalt	BJH-08-93
SFT-1	LSA Cobalt	BJH-08-93
SFT-2	LSA Cobalt	BJH-08-93
SFT-3	LAS Cobalt	BJH-08-93
SFT-4	LSA Cobalt	BJH-08-93
SFT-5	LSA Cobalt	BJH-08-93
SFT-6	LSA Cobalt	BJH-08-93
SFT-7	LSA Cobalt	BJH-08-93
A-1	HSA Cobalt	BJH-02-92
A-2	HSA Cobalt	BJH-02-92
A-3	IASFR	
A-4	HSA Cobalt	BJH-02-92
A-5	HSA Cobalt	BJH-02-92
A-6	HSA Cobalt	BJH-02-92
A-7	HSA Cobalt	BJH-02-92
A-8	HSA Cobalt	BJH-02-92
A-9	HSA Cobalt	RAK-04-02
A-10	HSA Cobalt	RAK-04-02
A-11	HSA Cobalt	RAK-04-02
A-12	SFROP	
A-13	LSFR	
A-14	LSFR	
A-15	LSFR	
A-16	LSFR	
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	DWG. 600271

Table A4. Continued

Facility	Description	Reference
B-8	YSFR	
B-9	Aluminum Filler	
B-10	Aluminum Filler	
B-11	Aluminum Filler	
B-12	Aluminum Filler	
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	HSA Cobalt	TMS-06-08
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	Aluminum Filler	
I-22	UCSB-2	TLM-01-11
I-23	Aluminum Filler	
I-24	AGR-2	SBG-01-11, Rev. 1

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Table A5. Summary of ATR Shim Positions for ATR Cycle 150A

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	79.3	1 2 3 4 5 6	79.3	1 2 3 4 5 6	79.3	1 2 3 5 6	79.3	1 2 3 5 6
0	75.2	1 2 3 4 5 6	75.2	1 2 3 4 5 6	85.4	1 2 3 5 6	85.4	1 2 3 5 6
1hi	85.4	1 2 3 4	85.4	1 2 3 4 5 6	100.1		100.1	
1lo	85.4	1 2 3	85.4	1 2 3 4	95.2		95.2	
3	85.4	1 2	85.4	1 2 3 4	95.2		95.2	
10	85.4		85.4	1 2 3	100.1		100.1	
13	85.4		85.4	1 2	104.2		104.2	

Table A6. Summary of ATR Core Power and Calculated $K_{effective}$ for ATR Cycle 150A

Time at Power (Days)	Total Core Power (MW)	Lobe Powers (MW) NW	NE	CR	SW	SE	$K_{effective}$
0	155	18.5	19.7	31.6	44.6	40.7	0.9898
0	155	17.3	18.4	31.1	46.2	42.0	0.9942
1hi	155	17.4	17.1	33.1	45.2	42.1	1.0023
1lo	141	16.7	17.2	30.8	39.4	36.9	1.0020
3	141	17.4	17.5	31.0	38.8	36.3	1.0006
10	141	17.4	17.5	30.7	39.5	36.0	1.0015
13	141	16.9	17.5	30.4	39.9	36.4	1.0024

Table A7. Summary of ATR Shim Positions for ATR Cycle 150A 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	75.2	1 1 1 1 1 1	85.4	1 1 1 0 1 1	0.0	1 1 1 0 1 1
NE	75.2	1 1 1 1 1 1	153.9	1 1 1 1 1 1	0.0	1 1 1 0 1 1	85.4	1 1 1 0 1 1
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	75.2	1 1 1 1 1 1	0.0	1 1 1 1 1 1	153.9	1 1 1 0 1 1	85.4	1 1 1 0 1 1
SE	0.0	1 1 1 1 1 1	75.2	1 1 1 1 1 1	85.4	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	155	29.3003	19.1920	32.1114	51.8194	22.5768	**0.984351**
NE	155	18.0642	33.8814	31.9877	23.7964	47.2703	**0.982418**
CR	155	19.9915	21.2343	45.4378	35.2360	33.1004	**0.987837**
SW	155	16.1464	10.5667	29.2078	63.3499	35.7292	**1.013110**
SE	155	10.3935	17.2939	39.3385	39.6401	58.3339	**1.010283**

Table A9. Summary of Fuel Element Powers for ATR Cycle 150A

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	155.0	3.1	2.9	2.6	2.0	1.8	1.9	2.3	3.0	3.3	3.6
0	155.0	2.9	2.7	2.4	1.8	1.6	1.7	2.1	2.8	3.2	3.5
1hi	155.0	2.8	2.5	2.2	1.7	1.5	1.6	1.9	2.7	3.0	3.5
1lo	141.0	2.8	2.7	2.2	1.7	1.5	1.6	1.9	2.6	3.0	3.3
3	141.0	2.8	2.7	2.3	1.7	1.5	1.6	1.9	2.6	3.1	3.3
10	141.0	2.9	2.8	2.3	1.7	1.5	1.6	1.9	2.6	3.1	3.3
13	141.0	2.9	2.8	2.3	1.7	1.5	1.6	1.9	2.6	3.1	3.3

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	155.0	4.3	5.1	5.0	4.8	4.7	4.8	5.1	5.9	5.3	4.7
0	155.0	4.2	5.1	5.1	5.0	5.0	5.1	5.3	6.0	5.4	4.7
1hi	155.0	4.7	5.5	5.1	4.9	4.8	4.9	5.2	5.9	5.8	5.3
1lo	141.0	4.3	4.9	4.5	4.2	4.1	4.2	4.5	5.2	5.2	4.8
3	141.0	4.3	4.9	4.5	4.2	4.0	4.1	4.4	5.1	5.1	4.8
10	141.0	4.1	4.8	4.4	4.2	4.1	4.2	4.4	5.1	5.0	4.6
13	141.0	4.1	4.7	4.4	4.2	4.2	4.3	4.5	5.1	4.9	4.5

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	155.0	4.8	5.8	6.2	5.6	5.3	5.2	5.3	5.7	5.5	4.3
0	155.0	4.8	5.9	6.4	5.8	5.6	5.5	5.6	5.9	5.5	4.2
1hi	155.0	5.4	6.2	6.2	5.5	5.3	5.3	5.3	5.6	5.8	4.7
1lo	141.0	4.8	5.5	5.4	4.8	4.5	4.5	4.6	5.0	5.2	4.3
3	141.0	4.8	5.5	5.3	4.7	4.4	4.4	4.5	4.9	5.1	4.3
10	141.0	4.6	5.4	5.4	4.8	4.6	4.6	4.6	5.0	5.1	4.2
13	141.0	4.6	5.4	5.4	4.9	4.7	4.7	4.7	5.0	5.1	4.2

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	155.0	3.7	3.1	2.8	2.0	1.7	1.6	1.9	2.5	2.8	3.1
0	155.0	3.6	3.0	2.7	1.9	1.5	1.5	1.7	2.4	2.7	3.0
1hi	155.0	3.7	3.1	2.7	1.9	1.5	1.5	1.7	2.3	2.7	3.0
1lo	141.0	3.5	3.0	2.5	1.8	1.4	1.4	1.6	2.2	2.7	2.9
3	141.0	3.6	3.1	2.6	1.9	1.5	1.5	1.7	2.3	2.8	3.1
10	141.0	3.7	3.1	2.6	1.8	1.5	1.5	1.7	2.3	2.9	3.2
13	141.0	3.6	3.1	2.5	1.8	1.4	1.4	1.6	2.2	2.8	3.2

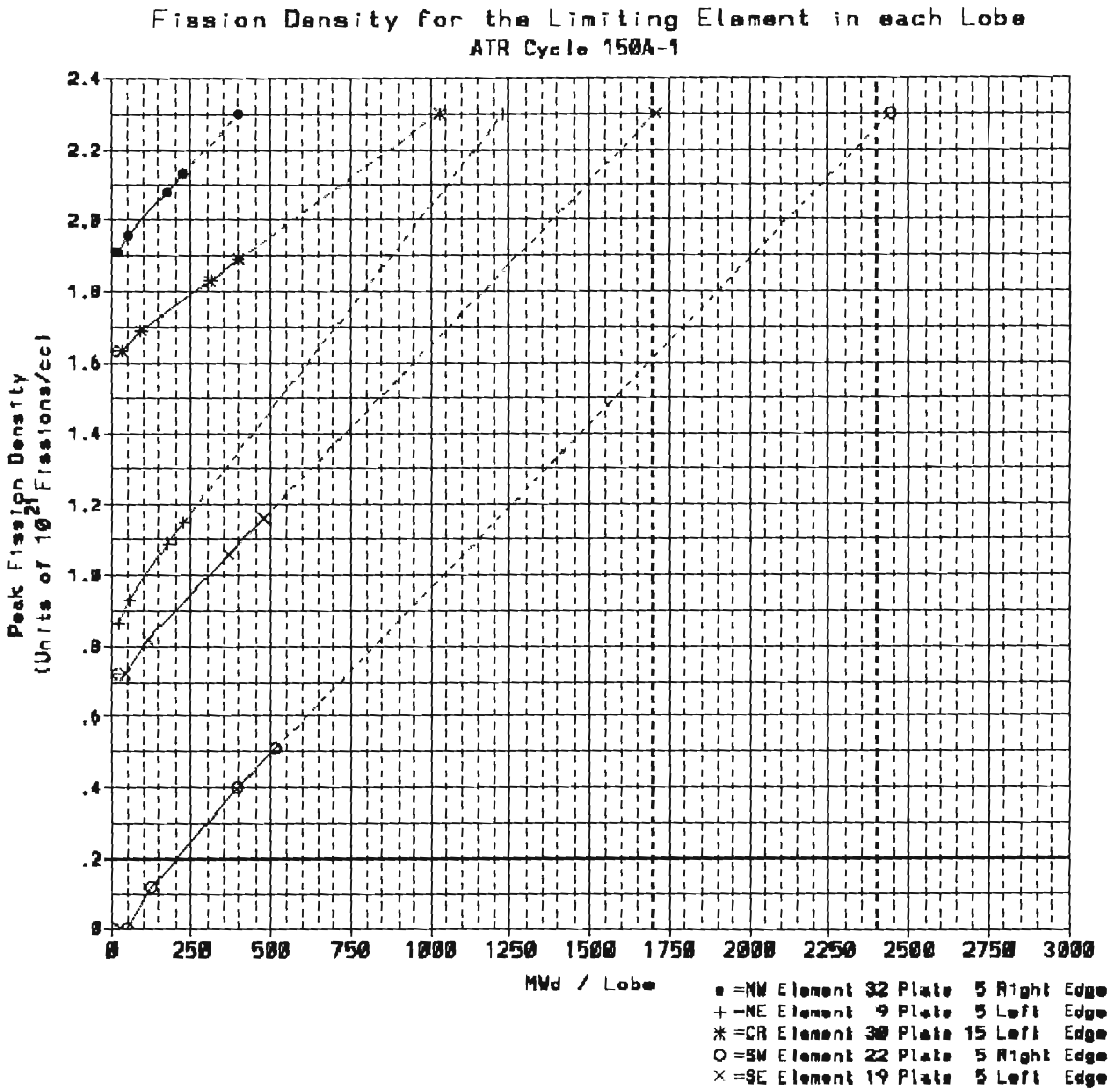

Figure A1. Fission Density for the Limiting Element in each Lobe For Cycle 150A-1

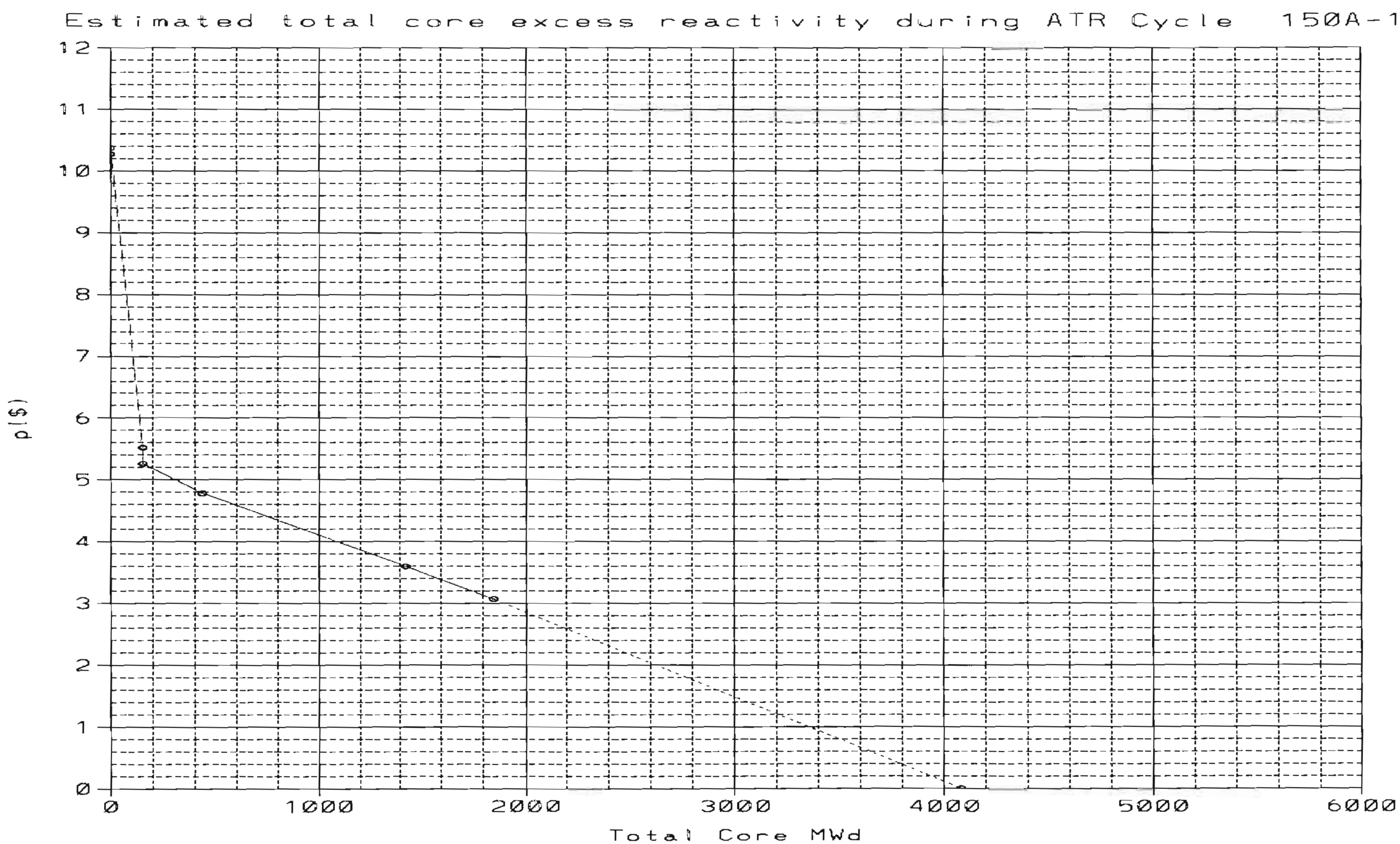

Figure A2. Estimated Total Core Excess Reactivity During ATR Cycle 150A-1