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As-run physics analysis for the EPRI-2 experiment for cycle 153B

Joseph W Nielsen, John Howard Jackson

April 2020

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ENGINEERING CALCULATIONS AND ANALYSIS REPORT

Title: As-Run Physics Analysis for the EPRI-2 Experiment for Cycle 153B.

ECAR No.: 2281 ECAR Rev. No.: 0 Project File No.: 29584 Date: July 2013

1. Quality Level (QL) No.	2	**Professional Engineer's Stamp** See LWP-10010 for requirements.
2. QL Determination No.	ALL-000747	
3. Engineering Job (EJ) No.	X	
4. SSC ID	X	
5. Building	X	
6. Site Area	X	

7. Objective/Purpose:

The purpose of this ECAR is to document the as-run physics analysis and source term in Curies and decay heat rate (Watts) for the shipment of the EPRI-2 experiment located in the Center Flux Trap (CFT). EPRI-2 was irradiated during cycle 153B. The experiment irradiation ended on April 13, 2013.

The as-run heat rates and flux/fluence results were calculated using the MCNP ATR full core model. The heat rates and flux are calculated based on an average center lobe power of 30.8 MW. The fluence is based on the operating time of 13.45 days.

ORIGEN2 Version 2.2 is used to determine the decay heat rate, gamma spectrum, and source term for the EPRI-2 experiment. The source term analysis was performed as requested by the project staff to demonstrate compliance with shipping requirements in the GE-2000 cask following irradiation as well as provide an estimated source term to support Post-Irradiation Examination as needed.

8. If revision, please state the reason and list sections and/or pages being affected:

9. Conclusions/Recommendations:

The EPRI-2 experiment was modeled in MCNP to provide as-run flux, fluence, heat rates, and source term for the test train. The as-run fluence and heat rates may be used to support post irradiation examination (PIE) of the specimens. The source term is intended to support shipment of the four sample holders including samples from ATR to MFC. The as-run flux and fluence results are reported in Table 6. The as-run heat rates are reported in Table 7 through Table 10. The source term for shipment is presented in Table 11. The decay heat rates for shipment of the test train are reported in Table 12.

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PROJECT ROLES AND RESPONSIBILITIES

Project Role	Name (Typed)	Organization	Pages covered (if applicable)
Performer	J. W. Nielsen	C660	
Checker[a]	C. R. Glass	C660	
Independent Reviewer[b]			
CUI Reviewer[c]	C. R. Glass	C660	
Manager[d]	D. J. Schoonen	C660	
Requestor[e]	Kevin Clayton	C630	
ATR Experiment Systems	N/A	C630	
Document Owner[e]	Kevin Clayton	C630	

Responsibilities:

a. Confirmation of completeness, mathematical accuracy, and correctness of data and appropriateness of assumptions.

b. Concurrence of method or approach. See definition, LWP-10106.

c. Concurrence with the document's markings in accordance with LWP-11202.

d. Concurrence of procedure compliance. Concurrence with method/approach and conclusion.

e. Concurrence with the document's assumptions and input information. See definition of Acceptance, LWP-10200.

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1.0 Introduction, Purpose, and Scope

The purpose of this ECAR is to document the as-run physics analysis and source term in Curies and decay heat rate (Watts) for the shipment of the EPRI-2 experiment located in the Center Flux Trap (CFT). EPRI-2 was irradiated during cycle 153B. The experiment irradiation ended on April 13, 2013.

The as-run heat rates and flux/fluence results were calculated using the MCNP ATR full core model. The heat rates and flux are calculated based on an average center lobe power of 30.8 MW. The fluence is based on the operating time of 13.45 days.

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2.0 Assumptions

The assumptions used in this analysis are stated below:

1. The MCNP models of ATR use three radial fuel regions to represent the ATR fuel elements (FEs)
2. ATR Cycle 153B cycle-averaged lobe powers are reported to be 19.7-19.7-30.8-35.4-44.0 MW (NW-NE-C-SW-SE) (Appendix B).
3. The ATR Cycle 153B as-run cycle length was 13.45 effective full power days (EFPD) (Appendix B)
4. The as-run hourly lobe power history for ATR Cycle 153B (see Attachment B) may be used to scale the MCNP-calculated EPRI-2 heat rate results to represent specific operating conditions for specific times. To scale the EPRI-2 results, the calculated results should be multiplied by the ratio of the desired center lobe power to the analyzed center lobe power. The scaling equation is defined to be, $HGR_{desired} = HGR_{analyzed} \times C_{desired} / C_{analyzed}$ (e.g. to scale HGR values at 26 MW center lobe power to HGR values at 30 MW center lobe power, $HGR_{30\ MW} = HGR_{26\ MW} \times 30\ MW / 26\ MW$). This scaling method may also be used to adjust MCNP-calculated power dependent EPRI-2 neutron fluxes.

3.0 Experiment Description

The following sections provide a description of the EPRI-2 experiment and the pressurized water loop (Loop 2A) located in the CFT.

Pressurized Water Loop Description

The dimensions of the pressurized water loop are based on the dimensions of a standard in-pile tube, which are documented in Reference [7]. The CFT consists of a water-filled flow tube with an inner radius of 2.21615 cm. The SS348 flow tube is 0.1651 cm thick. Outside of the flow tube is a pressure tube with an inner radius of 2.69621 cm. The pressure tube is 0.51689 cm thick, and is constructed of SS348. Outside of the pressure tube is an insulation gap with a thickness of 0.12827 cm and filled with helium, followed by an insulation tube with an outer radius of 3.65125 cm, and constructed of SS348. The insulation tube fits into the H-position housing, which has an inner radius of 4.097 cm. A cross-sectional diagram of the IPT assembly with EPRI-2 Compact Tension (CT) specimens is shown in Figure 1.

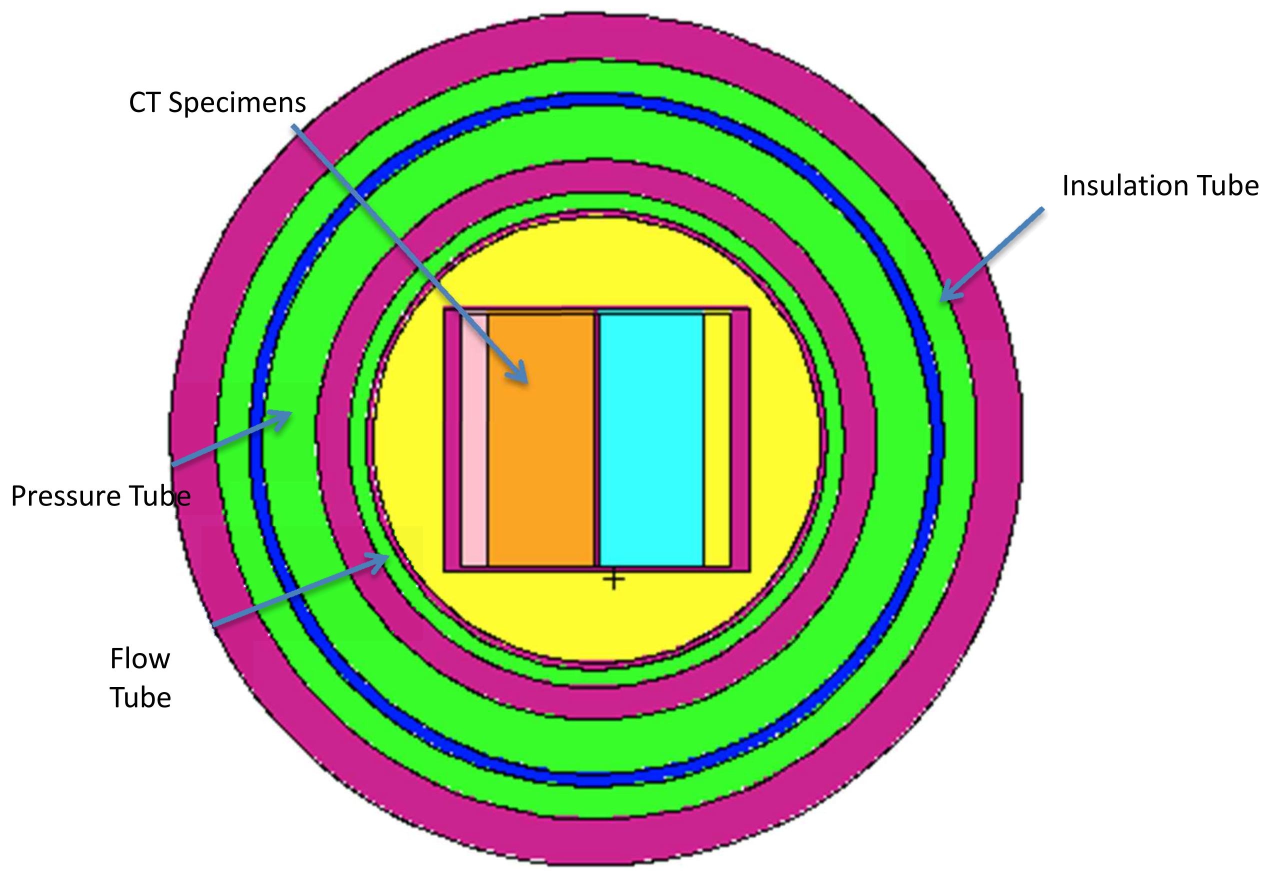

Figure 1. Diagram of a typical In-Pile Tube Assembly in ATR.

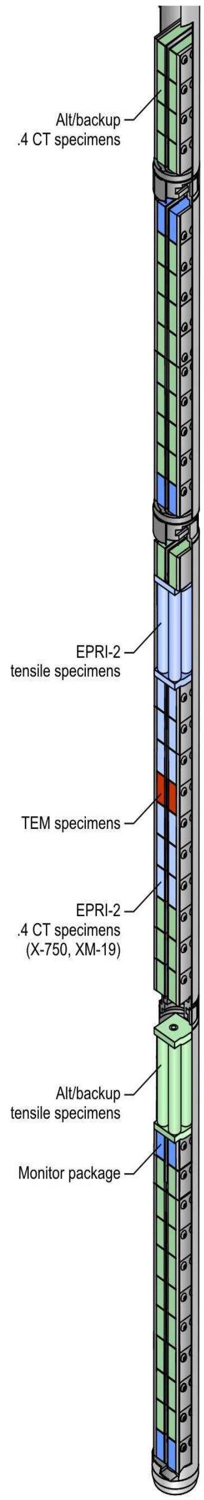

Figure 2. Diagram of the EPRI-2 Experiment Test Trains.

EPRI Experiment Test Train Description

The experiment test train has been designed to insert into the IPT. The test train is similar to other test trains used in the experiment loop facilities at ATR. The EPRI-1/2 experiment test trains consists of four holder assemblies each containing CT specimens with the 2 assemblies (Assembly 1 and Assembly 2) containing tensile specimens for the EPRI-1/2 experiment. A diagram of the EPRI-1/2 test train is presented in Figure 2. Alternate CT/backup specimens are located in the upper two assemblies, Assemblies 3 and 4.

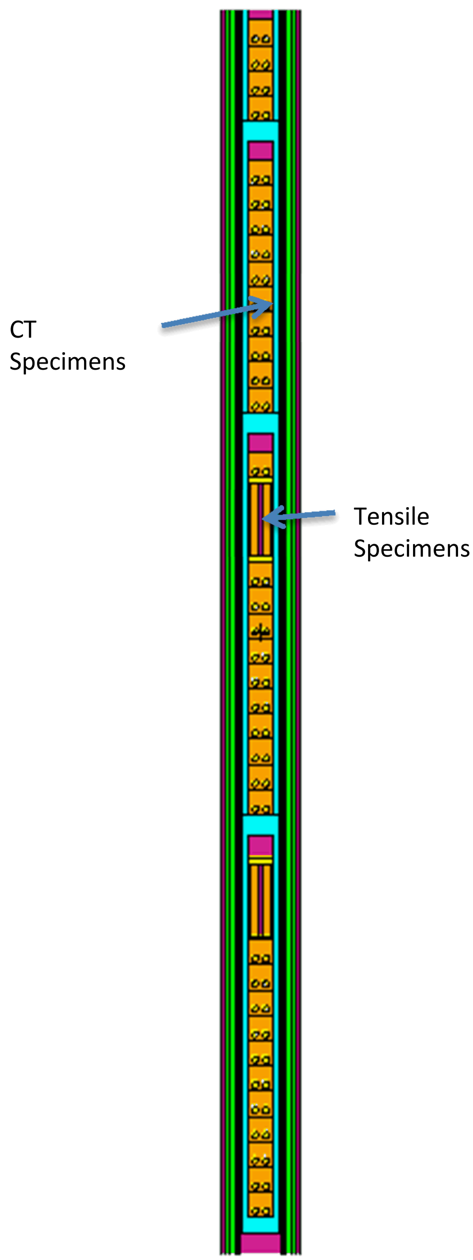

Figure 3. MCNP Diagram of the EPRI-1/2 Experiment

4.0 Model Description and Data

MCNP [1] [2] a general purpose Monte Carlo N-Particle transport code, was used to model and evaluate the EPRI experiment test trains. The EPRI-1/2 experiment was modeled based on the dimensions provided by drawings listed in Table 1. The pressurized water loop was modeled with the same nominal dimensions as the other standard experiment loops in ATR. A diagram of the MCNP models for the EPRI-1/2 MCNP model is presented in Figure 3.

Table 1. Loop 2A Backup Configuration Details.

INL Drawing	Drawing Title
601546	ATR NSUF IN-PILE TUBE TEST TRAIN EPRI 1, 2, and 3, PROJECT BACK-UP AND MONITOR PACKAGE DETAILS AND ASSEMBLIES
601547	ATR NSUF IN-PILE TUBE TEST TRAIN EPRI 1, 2, AND 3 TENSILE SPECIMEN PACKAGE DETAILS AND ASSEMBLIES
601549	ATR NSUF EPRI-3 IN-PILE TUBE TEST TRAIN EPRI-3 IN-CORE ASSEMBLIES
601752	ATR NSUF EPRI-3 IN-PILE TUBE TEST TRAIN EPRI-3 STACK-UP ASSEMBLIES

4.1 Mass Calculations

The mass values for the various components are needed to support the source term analysis. Appendix C contains mass calculations derived for components from the drawings used to construct the EPRI-2 test train. A summary of the mass values and material values are presented in Table 2. The composition of each material is included in Attachment C.

Table 2. Mass values used to support source term analysis.

Material	Component	Unit Mass (lb)	Quantity	Unit Mass (grams)	Total Mass (grams)
	Zirconium Holders				
	2A Zirc Holder	4.021	1	1823.89	1823.89
	2B Zirc Holder	4.1	1	1859.73	1859.73
	2C Zirc Holder	3.067	1	1391.17	1391.17
Zircaloy	2D Zirc Holder	4.927	1	2234.85	2234.85
	XM-19 Speicmen Package	0.0252	3	11.43	34.29
	XM-750 Specimen Package	0.0252	3	11.43	34.29
	PBU Specimen Package	0.0252	25	11.43	285.76
	PBU Specimens (2 per package)	0.204	25	92.53	2313.32
	Monitor Package	0.252	5	114.31	571.53
	Specimen Blocks	0.2	5	90.72	453.59
304 SST	Tensile Package	0.503	2	228.16	456.31
Nitronic 60	Backplates (1 per package)	0.024	36	10.89	391.90
	XM-19 Specimen Package (2 per package)	0.204	3	92.53	277.60
XM-19	XM-19 Tensile	0.503	1	228.16	228.16
	X-750 Specimen Package (2 per Package)	0.214	3	97.07	291.21
X-750	XM-750 Tensile	0.503	1	228.16	228.16

5.0 Software

The computer codes MCNP and ORIGEN2 are listed in the INL Enterprise Architecture (EA) Repository and are accepted as qualified scientific and engineering analysis software. Table 3 lists the version and EA ID for the computer codes used to perform the calculations and analyses documented by this ECAR.

Table 3. INL Qualified Analysis Software, Version, and EA ID.

Code Name	Version	EA ID
MCNP	5 (Release 1.40)	234166 [5]
ORIGEN2	2.2	201298 [9]

MCNP has been verified and validated (V&V'd) for use at the INL as documented by the MCNP Version 5, Release 1.40 software management report [5]. The MCNP Version 5, Release 1.40 V&V process was performed and accepted on high performance computing (HPC) systems at the INL.

ORIGEN2 [8] has been V&V'd for use at the INL as documented by the ORIGEN2 Version 2.2 software management plan [9].

The computer configurations listed in Table 4 and Table 5 were used to perform the MCNP5 and ORIGEN 2 calculations respectively.

Table 4: Computer Configurations for INL Qualified MCNP5 installations.

Model of Computer	Processor	Operating System
fission is an Appro (Xtreme-X™ Supercomputer Series) distributed memory cluster	Two service nodes acting as login nodes each with: • Two 8 core 2.4 GHz AMD Opteron (6136) processors • 32 GB of shared memory (2 GB/core) 391 compute blades with: • Four 8 core 2.4 GHz AMD Opteron (6136) processors per blade (32 cores/node and 12512 cores total) • 64 GB of shared memory per node (2 GB/core) QDR InfiniBand interconnect network	RedHat Linux Enterprise Server 5.5
Icestorm SGI Altix ICE 8200 distributed memory blade cluster	256 compute blades with two quad core Intel Xeon processors each 2,048 compute cores total, 2.66 GHz clock speed 2 login nodes, each with 8 cores 2 GB memory per core, 4 TB memory total DDR 4X InfiniBand interconnect network	SUSE Linux Enterprise Server 10

Table 5: Computer Configuration for INL Qualified ORIGEN2 installation.

Computer Model	Processor	Operating System
Dell Precision 670	Dual Intel Xeon	Windows XP
Apple Mac Pro	Dual Intel Quad Xeon	OS X version 10.5

6.0 Analysis Results

The as-run physics analysis is used to determine the as-run heat rates, flux, fluence, and source term for the EPRI-2 experiments. The calculated flux the experiment at an average center lobe power of 30.8 MW and the corresponding cumulative fast fluence (>1.0 MeV) for 13.45 days is presented in Table 6. The calculated heat rates for a center lobe power of 30.8 MW is presented in Table 7 through Table 10.

The source term is provided for the proposed shipping date of July 15, 2013, which is approximately 3 months or 90 days from the shutdown date of April 13. The total flux was conservatively assumed to be 1.0×10^{15} n/cm^2-s, which corresponds to the flux near core mid-plane. The calculated source term for the EPRI-2 experiment is provided in Table 11. The source term is for the four specimen holders and specimens located in the test train. The decay heat rates obtained from ORIGEN are also presented in this analysis. The results for the decay heat rates for the EPRI-2 experiment are presented in Table 12.

Table 6. Fast flux (>1.0 MeV) and fast fluence results for EPRI-2 test train.

Calculated Flux (n/cm^2-sec)	Calculated Fluence (n/cm^2)	EPRI-2 Holder	Package
2.93E+13	3.41E+19	EPRI-2D	EPRI-2D4
3.96E+13	4.60E+19		EPRI-2D3
5.06E+13	5.88E+19		EPRI-2D2
6.12E+13	7.11E+19		EPRI-2D1

8.66E+13	1.01E+20	EPRI-2C	EPRI-2C10
1.01E+14	1.18E+20		EPRI-2C9
1.12E+14	1.30E+20		EPRI-2C8
1.22E+14	1.41E+20		EPRI-2C7
1.31E+14	1.52E+20		EPRI-2C6
1.38E+14	1.60E+20		EPRI-2C5
1.43E+14	1.66E+20		EPRI-2C4
1.48E+14	1.73E+20		EPRI-2C3
1.54E+14	1.78E+20		EPRI-2C2
1.55E+14	1.80E+20		EPRI-2C1
1.57E+14	1.83E+20	EPRI-2B	EPRI-2B14
1.57E+14	1.83E+20		EPRI-2B 11-13
1.63E+14	1.89E+20		EPRI-2B10
1.65E+14	1.91E+20		EPRI-2B9
1.66E+14	1.93E+20		EPRI-2B8
1.67E+14	1.93E+20		EPRI-2B7
1.66E+14	1.92E+20		EPRI-2B6
1.66E+14	1.93E+20		EPRI-2B5
1.67E+14	1.94E+20		EPRI-2B4
1.64E+14	1.91E+20		EPRI-2B3
1.63E+14	1.90E+20		EPRI-2B2
1.61E+14	1.88E+20		EPRI-2B1
1.48E+14	1.72E+20	EPRI-2A	EPRI-2A 12-14
1.47E+14	1.71E+20		EPRI-2A-11
1.42E+14	1.65E+20		EPRI-2A-10
1.37E+14	1.60E+20		EPRI-2A-9
1.30E+14	1.51E+20		EPRI-2A-8
1.23E+14	1.42E+20		EPRI-2A-7
1.12E+14	1.30E+20		EPRI-2A-6
1.03E+14	1.20E+20		EPRI-2A-5
9.24E+13	1.07E+20		EPRI-2A-4
8.06E+13	9.36E+19		EPRI-2A-3
6.89E+13	8.01E+19		EPRI-2A-2
5.53E+13	6.43E+19		EPRI-2A-1

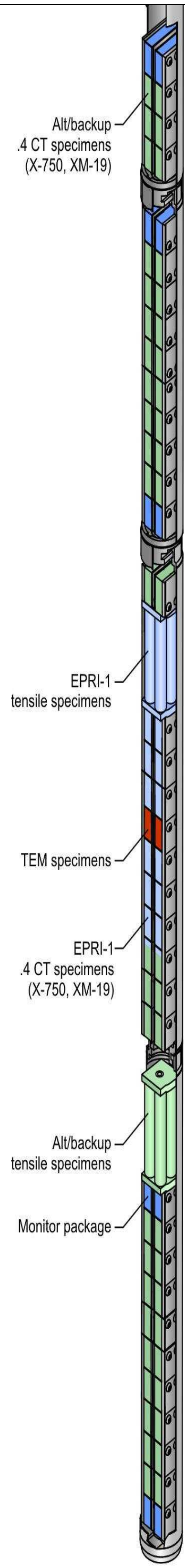

Table 7. Calculated heat rates for EPRI-2A Holder.

Package	Water between specimens (W/g)	Screws (W/g)	X-750 CT (W/g)	XM-19 CT (W/g)	SS Front Plate (W/g)	Nitronic 60 Back Plate (W/g)	Water outside of specimens inside of holder (W/g)	Holder Assembly (W/g)
								2.52
EPRI-2A-1	5.80	2.62	2.81	2.85	2.66	2.81	5.72	3.15
EPRI-2A-2	6.97	3.01	3.23	3.23	3.10	3.20	6.88	3.61
EPRI-2A-3	8.09	3.42	3.60	3.62	3.47	3.60	8.00	4.09
EPRI-2A-4	9.15	3.81	4.04	4.05	3.86	4.03	9.01	4.61
EPRI-2A-5	10.21	4.25	4.47	4.49	4.25	4.45	10.09	5.05
EPRI-2A-6	11.19	4.66	4.88	4.89	4.68	4.86	11.11	5.52
EPRI-2A-7	12.08	5.01	5.27	5.28	5.06	5.24	11.95	5.98
EPRI-2A-8	12.94	5.37	5.63	5.67	5.40	5.61	12.80	6.41
EPRI-2A-9	13.63	5.74	6.00	6.00	5.74	5.93	13.53	6.77
EPRI-2A-10	14.27	6.02	6.30	6.26	5.98	6.25	14.08	7.11
EPRI-2A-11	14.69	6.29	6.64	6.63	6.38	6.56	14.60	7.46
	Lower Support Plate (W/g)	**Upper Support Plate (W/g)**	**Tensile 1 (W/g)**	**Tensile 2 (W/g)**	**Tensile 3 (W/g)**	**Tensile 4 (W/g)**	**Water outside of specimens inside of holder (W/g**	**Holder (W/g)**
EPRI-2A-12-14	7.62	7.38	7.21	7.27	7.41	7.30	15.31	8.19
							15.35	8.02

Table 8. Calculated heat rates for EPRI-2B Holder.

Package	Water between specimens (W/g)	Screws (W/g)	X-750 CT (W/g)	XM-19 CT (W/g)	SS Front Plate (W/g)	Nitronic 60 Back Plate (W/g)	Water outside of specimens inside of holder (W/g)	Holder Assembly (W/g)
EPRI-2B-1								
EPRI-2B-2	16.37	7.26	7.57	7.54	7.25	7.41	16.30	8.52
EPRI-2B-3	16.51	7.28	7.55	7.55	7.16	7.48	16.48	8.50
EPRI-2B-4	16.65	7.34	7.55	7.56	7.26	7.44	16.59	8.56
EPRI-2B-5	16.68	7.29	7.54	7.57	7.20	7.50	16.62	8.63
EPRI-2B-6	16.77	7.32	7.59	7.59	7.31	7.52	16.67	8.69
EPRI-2B-7	16.89	7.36	7.65	7.62	7.30	7.49	16.70	8.70
EPRI-2B-8	16.87	7.32	7.62	7.61	7.33	7.51	16.70	8.69
EPRI-2B-9	16.69	7.39	7.63	7.58	7.35	7.51	16.69	8.70
EPRI-2B-10	16.71	7.34	7.64	7.62	7.36	7.55	16.68	8.65
EPRI-2B-11	16.72	7.40	7.72	7.67	7.39	7.56	16.66	8.72
	Lower Support Plate (W/g)	**Upper Support Plate (W/g)**	**Tensile 1 (W/g)**	**Tensile 2 (W/g)**	**Tensile 3 (W/g)**	**Tensile 4 (W/g)**	**Water outside of specimens inside of holder (W/g)**	**Holder (W/g)**
EPRI-2B-12-14	7.37	7.25	8.05	8.06	8.15	8.09	16.16	8.75
	Water between specimens (W/g)	**Screws (W/g)**	**X-750 CT (W/g)**	**XM-19 CT (W/g)**	**SS Front Plate (W/g)**	**Nitronic 60 Back Plate (W/g)**	**Water outside of specimens inside of holder (W/g)**	**Holder Assembly (W/g)**
EPRI-2B-15	16.15	7.25	7.67	7.66	7.25	7.55	16.02	8.51
							15.21	7.81

Table 9. Calculated heat rates for EPRI-2C Holder.

Package	Water between specimens (W/g)	Screws (W/g)	X-750 CT (W/g)	XM-19 CT (W/g)	SS Front Plate (W/g)	Nitronic 60 Back Plate (W/g)	Water outside of specimens inside of holder (W/g)	Holder Assembly (W/g)
EPRI-2C-1	15.57	6.94	7.04	7.05	6.71	6.93	15.41	7.88
EPRI-2C-2	15.08	6.61	6.76	6.74	6.45	6.64	15.03	7.69
EPRI-2C-3	14.65	6.44	6.54	6.47	6.25	6.45	14.65	7.45
EPRI-2C-4	14.12	6.06	6.24	6.24	5.94	6.23	14.14	7.07
EPRI-2C-5	13.59	5.84	5.92	5.96	5.68	5.92	13.54	6.80
EPRI-2C-6	12.94	5.56	5.60	5.63	5.39	5.62	12.85	6.40
EPRI-2C-7	12.07	5.25	5.26	5.29	5.04	5.22	12.00	5.98
EPRI-2C-8	11.16	4.81	4.85	4.86	4.65	4.81	11.06	5.51
EPRI-2C-9	10.07	4.46	4.43	4.44	4.24	4.38	10.01	5.03
EPRI-2C-10	8.70	4.00	4.04	4.03	3.76	3.94	9.32	4.53
							7.44	3.65

Table 10. Calculated heat rates for EPRI-2D Holder.

Package	Water between specimens (W/g)	Screws (W/g)	X-750 CT (W/g)	XM-19 CT (W/g)	SS Front Plate (W/g)	Nitronic 60 Back Plate (W/g)	Water outside of specimens inside of holder (W/g)	Holder Assembly (W/g)
EPRI-2D-1	6.20	2.95	2.92	2.91	2.78	2.89	6.24	3.27
EPRI-2D-2	5.18	2.56	2.48	2.49	2.36	2.46	5.25	2.82
EPRI-2D-3	4.28	2.15	2.13	2.14	2.04	2.09	4.26	2.38
EPRI-2D-4	3.38	1.82	1.81	1.81	1.68	1.77	3.46	2.00
							2.47	1.64
							1.88	1.34
							1.41	1.07
							1.06	0.84
							0.80	0.66

Table 11. Calculated source term for EPRI-2 test train (Ci).

Nuclide	153B_EOC	7.0D	14.0D	30.0D	45.0D	60.0D	80.0D	100.0D	120.0D	140.0D	160.0D
HE 6	9.22E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BE 8	1.59E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B 12	1.63E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C 14	4.25E-03	4.25E-03	4.25E-03	4.25E-03	4.25E-03	4.25E-03	4.25E-03	4.25E-03	4.25E-03	4.25E-03	4.25E-03
NE 23	6.94E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA 24	6.97E-01	2.97E-04	1.26E-07	2.48E-15	1.48E-22	8.82E-30	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA 25	4.19E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MG 27	2.59E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
AL 28	7.99E+01	2.98E-11	1.14E-13	3.37E-19	2.21E-24	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
AL 29	8.37E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
AL 30	8.12E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SI 31	1.83E+01	9.35E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
P 32	1.49E+01	1.06E+01	7.54E+00	3.47E+00	1.68E+00	8.11E-01	3.08E-01	1.17E-01	4.42E-02	1.68E-02	6.37E-03
P 33	3.07E-04	2.53E-04	2.08E-04	1.34E-04	8.81E-05	5.81E-05	3.34E-05	1.92E-05	1.10E-05	6.33E-06	3.63E-06
P 34	5.78E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
S 35	6.65E-02	6.30E-02	5.96E-02	5.25E-02	4.67E-02	4.15E-02	3.54E-02	3.03E-02	2.59E-02	2.21E-02	1.89E-02
S 37	1.67E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CA 45	5.94E-04	5.77E-04	5.60E-04	5.23E-04	4.91E-04	4.61E-04	4.23E-04	3.89E-04	3.57E-04	3.28E-04	3.01E-04
CA 47	2.64E-05	9.07E-06	3.11E-06	2.70E-07	2.73E-08	2.76E-09	1.30E-10	6.10E-12	2.87E-13	1.35E-14	6.35E-16
SC 46	1.46E-01	1.38E-01	1.30E-01	1.14E-01	1.01E-01	8.89E-02	7.53E-02	6.38E-02	5.41E-02	4.59E-02	3.89E-02
SC 47	2.01E+00	4.73E-01	1.11E-01	4.06E-03	1.83E-04	8.21E-06	1.31E-07	2.11E-09	3.45E-11	5.84E-13	1.09E-14
SC 48	2.01E-01	1.41E-02	9.88E-04	2.27E-06	7.61E-09	2.55E-11	1.28E-14	6.46E-18	3.25E-21	1.63E-24	8.21E-28
SC 49	1.65E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SC 50	3.41E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TI 51	3.98E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
V 52	1.39E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
V 53	9.96E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
V 54	1.00E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	153B_EOC	7.0D	14.0D	30.0D	45.0D	60.0D	80.0D	100.0D	120.0D	140.0D	160.0D
CR 51	6.31E+03	5.30E+03	4.45E+03	2.98E+03	2.05E+03	1.41E+03	8.53E+02	5.17E+02	3.14E+02	1.90E+02	1.15E+02
CR 55	2.87E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MN 54	3.33E+01	3.28E+01	3.23E+01	3.12E+01	3.01E+01	2.92E+01	2.79E+01	2.67E+01	2.55E+01	2.44E+01	2.34E+01
MN 56	5.29E+04	1.29E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MN 57	2.58E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MN 58	8.58E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FE 55	1.18E+02	1.18E+02	1.17E+02	1.16E+02	1.14E+02	1.13E+02	1.11E+02	1.10E+02	1.08E+02	1.07E+02	1.05E+02
FE 59	6.41E+01	5.75E+01	5.16E+01	4.04E+01	3.20E+01	2.54E+01	1.87E+01	1.37E+01	1.01E+01	7.41E+00	5.45E+00
CO 58	4.01E+02	3.74E+02	3.50E+02	2.99E+02	2.58E+02	2.23E+02	1.83E+02	1.51E+02	1.24E+02	1.02E+02	8.37E+01
CO 60	2.50E+01	2.50E+01	2.49E+01	2.48E+01	2.46E+01	2.45E+01	2.43E+01	2.41E+01	2.40E+01	2.38E+01	2.36E+01
CO 60M	2.77E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO 61	3.24E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO 62	2.99E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NI 59	2.85E-02	2.85E-02	2.85E-02	2.85E-02	2.85E-02	2.85E-02	2.85E-02	2.85E-02	2.85E-02	2.85E-02	2.85E-02
NI 63	3.54E+00	3.54E+00	3.54E+00	3.54E+00	3.54E+00	3.54E+00	3.54E+00	3.54E+00	3.54E+00	3.53E+00	3.53E+00
NI 65	3.64E+02	3.11E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NI 66	1.03E-02	1.22E-03	1.45E-04	1.10E-06	1.14E-08	1.19E-10	2.69E-13	6.05E-16	4.46E-18	0.00E+00	0.00E+00
CU 64	3.28E+01	3.41E-03	3.56E-07	2.81E-16	8.24E-25	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CU 66	7.17E+00	1.22E-03	1.45E-04	1.11E-06	1.15E-08	1.19E-10	2.69E-13	6.08E-16	4.46E-18	1.01E-20	0.00E+00
CU 67	3.81E-05	5.80E-06	8.83E-07	1.20E-08	2.12E-10	3.75E-12	1.73E-14	7.75E-17	0.00E+00	0.00E+00	0.00E+00
ZN 65	2.33E-05	2.29E-05	2.24E-05	2.14E-05	2.05E-05	1.97E-05	1.86E-05	1.75E-05	1.66E-05	1.57E-05	1.48E-05
SR 89	8.34E-01	7.57E-01	6.88E-01	5.52E-01	4.50E-01	3.66E-01	2.78E-01	2.11E-01	1.61E-01	1.22E-01	9.27E-02
SR 91	9.52E-01	4.52E-06	2.15E-11	1.46E-23	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SR 93	3.29E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 89M	2.47E-03	5.61E-04	1.27E-04	4.27E-06	1.77E-07	7.37E-09	1.06E-10	1.53E-12	2.20E-14	3.18E-16	4.58E-18
Y 90	1.76E+02	2.85E+01	4.62E+00	7.22E-02	1.46E-03	2.99E-05	3.80E-07	2.17E-07	2.16E-07	2.15E-07	2.15E-07
Y 91	1.86E+00	1.72E+00	1.58E+00	1.31E+00	1.10E+00	9.17E-01	7.23E-01	5.71E-01	4.50E-01	3.55E-01	2.80E-01
Y 92	1.07E+01	5.49E-14	2.81E-28	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 93	3.28E-03	3.27E-08	3.21E-13	1.15E-24	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 94	6.81E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 96	4.38E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	153B_EOC	7.0D	14.0D	30.0D	45.0D	60.0D	80.0D	100.0D	120.0D	140.0D	160.0D
ZR 89	2.48E-03	5.62E-04	1.27E-04	4.28E-06	1.78E-07	7.38E-09	1.06E-10	1.53E-12	2.20E-14	3.19E-16	2.85E-18
ZR 93	1.98E-04	1.98E-04	1.98E-04	1.98E-04	1.98E-04	1.98E-04	1.98E-04	1.98E-04	1.98E-04	1.98E-04	1.98E-04
ZR 95	5.85E+02	5.42E+02	5.03E+02	4.23E+02	3.59E+02	3.05E+02	2.46E+02	1.98E+02	1.59E+02	1.28E+02	1.03E+02
ZR 97	6.32E+03	6.43E+00	6.56E-03	9.48E-10	3.67E-16	1.42E-22	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NB 92	3.14E-01	1.95E-01	1.21E-01	4.06E-02	1.46E-02	5.24E-03	1.34E-03	3.42E-04	8.75E-05	2.24E-05	5.71E-06
NB 93M	1.76E-07	3.59E-07	5.43E-07	9.60E-07	1.35E-06	1.74E-06	2.26E-06	2.78E-06	3.29E-06	3.81E-06	4.32E-06
NB 94	5.54E-04	5.54E-04	5.54E-04	5.54E-04	5.54E-04	5.54E-04	5.54E-04	5.54E-04	5.54E-04	5.54E-04	5.54E-04
NB 95	7.28E+01	1.36E+02	1.86E+02	2.60E+02	2.93E+02	3.02E+02	2.93E+02	2.69E+02	2.39E+02	2.08E+02	1.77E+02
NB 95M	2.67E+00	3.59E+00	3.62E+00	3.13E+00	2.67E+00	2.27E+00	1.82E+00	1.47E+00	1.18E+00	9.52E-01	7.67E-01
NB 96	2.41E-01	1.65E-03	1.12E-05	1.26E-10	2.88E-15	6.58E-20	4.26E-26	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NB 97	6.32E+03	6.46E+00	6.59E-03	1.02E-09	3.95E-16	1.53E-22	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NB 97M	5.98E+03	6.09E+00	6.22E-03	8.98E-10	3.48E-16	1.34E-22	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NB 98	1.10E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MO 93M	1.52E-01	6.29E-09	2.61E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MO 93	3.41E-05	3.41E-05	3.41E-05	3.41E-05	3.41E-05	3.41E-05	3.41E-05	3.41E-05	3.41E-05	3.41E-05	3.41E-05
MO 99	1.03E+02	1.76E+01	3.01E+00	5.34E-02	1.22E-03	2.78E-05	1.80E-07	1.16E-09	7.52E-12	4.86E-14	3.13E-16
MO101	2.65E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TC 99	1.13E-06	1.50E-06	1.57E-06	1.58E-06	1.58E-06	1.58E-06	1.58E-06	1.58E-06	1.58E-06	1.58E-06	1.58E-06
TC100	1.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TC101	2.65E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CD115	2.71E-04	3.07E-05	3.48E-06	2.40E-08	2.26E-10	2.12E-12	4.21E-15	1.14E-17	0.00E+00	0.00E+00	0.00E+00
CD117	3.38E-03	1.20E-22	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CD119	9.61E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
IN113M	6.98E+00	6.69E+00	6.42E+00	5.83E+00	5.32E+00	4.86E+00	4.31E+00	3.82E+00	3.39E+00	3.01E+00	2.66E+00
IN114	3.78E-01	1.91E-02	1.73E-02	1.38E-02	1.12E-02	9.09E-03	6.87E-03	5.19E-03	3.93E-03	2.97E-03	2.24E-03
IN114M	2.20E-02	2.00E-02	1.81E-02	1.45E-02	1.17E-02	9.50E-03	7.18E-03	5.43E-03	4.10E-03	3.10E-03	2.34E-03
IN116	3.90E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
IN116M	4.74E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
IN117	3.81E-02	3.32E-22	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
IN117M	3.15E-03	4.65E-22	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
IN118	1.27E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	153B_EOC	7.0D	14.0D	30.0D	45.0D	60.0D	80.0D	100.0D	120.0D	140.0D	160.0D
IN119	8.99E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
IN119M	9.61E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SN113	6.98E+00	6.69E+00	6.41E+00	5.82E+00	5.32E+00	4.86E+00	4.31E+00	3.82E+00	3.39E+00	3.00E+00	2.66E+00
SN113M	3.92E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SN117M	3.30E+02	2.33E+02	1.65E+02	7.47E+01	3.56E+01	1.69E+01	6.29E+00	2.34E+00	8.69E-01	3.23E-01	1.20E-01
SN119M	2.68E+01	2.63E+01	2.58E+01	2.46E+01	2.36E+01	2.26E+01	2.14E+01	2.02E+01	1.91E+01	1.80E+01	1.71E+01
SN121	3.24E+02	4.20E+00	5.45E-02	2.65E-06	2.40E-10	2.17E-14	8.80E-20	3.57E-25	1.45E-30	0.00E+00	0.00E+00
SN121M	9.67E-04	9.66E-04	9.66E-04	9.66E-04	9.65E-04	9.65E-04	9.64E-04	9.63E-04	9.62E-04	9.62E-04	9.61E-04
SN123	2.30E+00	2.22E+00	2.14E+00	1.96E+00	1.81E+00	1.67E+00	1.50E+00	1.35E+00	1.21E+00	1.09E+00	9.76E-01
SN123M	1.27E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SN125	1.31E+02	7.92E+01	4.79E+01	1.52E+01	5.15E+00	1.75E+00	4.16E-01	9.88E-02	2.35E-02	5.57E-03	1.32E-03
SN125M	1.67E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SB122	1.25E+00	2.07E-01	3.44E-02	5.66E-04	1.20E-05	2.56E-07	1.51E-09	8.89E-12	5.24E-14	3.06E-16	0.00E+00
SB122M	1.58E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SB124	2.62E-04	2.42E-04	2.23E-04	1.86E-04	1.56E-04	1.31E-04	1.04E-04	8.29E-05	6.58E-05	5.23E-05	4.15E-05
SB125	2.23E+00	2.71E+00	3.00E+00	3.27E+00	3.33E+00	3.33E+00	3.30E+00	3.26E+00	3.21E+00	3.17E+00	3.13E+00
SB126	5.41E-02	3.66E-02	2.47E-02	1.01E-02	4.37E-03	1.89E-03	6.17E-04	2.02E-04	6.59E-05	2.15E-05	7.04E-06
SB126M	1.99E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TE123M	8.66E-06	8.32E-06	7.99E-06	7.28E-06	6.67E-06	6.12E-06	5.45E-06	4.85E-06	4.32E-06	3.85E-06	3.43E-06
TE125M	3.58E-02	7.89E-02	1.26E-01	2.31E-01	3.18E-01	3.92E-01	4.70E-01	5.31E-01	5.76E-01	6.10E-01	6.34E-01
TA182	4.77E+00	4.57E+00	4.38E+00	3.98E+00	3.63E+00	3.32E+00	2.94E+00	2.61E+00	2.31E+00	2.05E+00	1.82E+00
TA182M	4.29E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TA183	2.82E+01	1.09E+01	4.20E+00	4.77E-01	6.22E-02	8.09E-03	5.34E-04	3.53E-05	2.33E-06	1.54E-07	1.01E-08
W181	4.47E-03	4.30E-03	4.13E-03	3.77E-03	3.46E-03	3.17E-03	2.83E-03	2.52E-03	2.25E-03	2.01E-03	1.79E-03
W183M	1.06E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W185	1.58E-01	1.48E-01	1.38E-01	1.19E-01	1.04E-01	9.05E-02	7.53E-02	6.26E-02	5.20E-02	4.33E-02	3.60E-02
W185M	1.49E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W187	3.84E+01	2.94E-01	2.25E-03	3.28E-08	9.57E-13	2.80E-17	2.52E-23	2.26E-29	0.00E+00	0.00E+00	0.00E+00
W188	3.97E-02	3.70E-02	3.45E-02	2.94E-02	2.53E-02	2.18E-02	1.78E-02	1.46E-02	1.20E-02	9.80E-03	8.02E-03
RE186	2.34E-03	6.47E-04	1.79E-04	9.50E-06	6.06E-07	3.86E-08	9.83E-10	2.50E-11	6.37E-13	1.62E-14	4.12E-16
RE188	5.23E-01	3.79E-02	3.49E-02	2.97E-02	2.56E-02	2.20E-02	1.80E-02	1.48E-02	1.21E-02	9.90E-03	8.11E-03

Nuclide	**153B_EOC**	**7.0D**	**14.0D**	**30.0D**	**45.0D**	**60.0D**	**80.0D**	**100.0D**	**120.0D**	**140.0D**	**160.0D**
RE188M	5.22E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SUMTOT	**8.43E+04**	**7.05E+03**	**6.00E+03**	**4.32E+03**	**3.25E+03**	**2.50E+03**	**1.81E+03**	**1.35E+03**	**1.04E+03**	**8.26E+02**	**6.71E+02**

Table 12. Calculated decay heat for EPRI-2 test train (Watts).

	153B_EOC	7.0D	14.0D	30.0D	45.0D	60.0D	80.0D	100.0D	120.0D	140.0D	160.0D
Decay Heat Rates	9.14E+02	9.32E+00	8.28E+00	7.02E+00	6.18E+00	5.48E+00	4.67E+00	3.98E+00	3.39E+00	2.89E+00	2.47E+00

7.0 References

[1] Tim Goorley, Jeffrey S. Bull, Forrest B. Brown, et. al., "Release of MCNP5_RSICC_1.30," Trans. Am. Nucl. Soc., Vol. 91, pp. 693-694 (2004).

[2] X-5 Monte Carlo Team, "MCNP—A General Monte Carlo N-Particle Transport Code, Version 5," Volume I, LA-UR-03-1987, Los Alamos National Laboratory, April 24, 2003 (Revised 6/30/2004) and Volume II, LA-CP-0245, Los Alamos National Laboratory, April 24, 2003 (Revised 6/30/2004) (Vol. II is available with a licensed copy of MCNP).

[3] T. Nakagawa, et al., "Japanese Evaluated Nuclear Data Library Version 3 Revision-2: JENDL-3.2," Journal of Nuclear Science and Technology, 32, pp. 1259-1271 (December 1995).

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[5] M. A. Lillo, J. R. Mitchell, "Software Management, MCNP Version 5, Release 1.40," INL/INT-08-15171 Rev. 0, August 2010, INL Record Number 234166.

[6] "MCNP5 Version 1.60 Software Management Plan," PLN-4099, Revision 0, January 2012

[7] S. S. Kim, B. G. Schnitzler, "Advanced Test Reactor: Serpentine Arrangement of Highly Enriched Water-Moderated Uranium-Aluminide Fuel Plates Reflected by Beryllium," INL/EXT-05-00780, September 2005; published in "International Handbook of Evaluated Criticality Safety Benchmark Experiments," NEA/NSC/DOC/(95)03/II, Volume II, HEU-MET-THERM-022, September 2005 Edition.

[8] A. G. Croff, "ORIGEN2: A Versatile Computer Code for Calculating the Nuclide Compositions and Characteristics of Nuclear Materials, Nuclear Technology," Vol. 62, pp. 335-352, 1983.

[9] J. R. Mitchell, J. W. Nielsen, "Software Management, ORIGEN2 Version 2.2," PLN-3710, Revision 0, October 2011, INL Record Number 3818329 (EA ID 201298).

[10] J. R. Parry, "Physics Evaluation for the AGR-3/4 Experiment Irradiated in the ATR NEFT in Support of Final Design Activities," ECAR-1346, Rev. 1, September 13, 2011.

[11] J. W. Nielsen, "ATR Physics Analysis of the AFIP-7 Experiment in the Center Flux Trap," ECAR-1262, Revision 0, May 2011.

[12] Lamarsh, J. R., "Introduction to Nuclear Engineering," 2nd Edition, 1983, pp350-351.

[13] "KNOVEL Steam Tables, An Implementation of Equations Published by the International Association for the Properties of Water and Steam (IAPWS)," http://www.knovel.com/web/portal/basic_search/display?_EXT_KNOVEL_DISPLAY_bookid=1251, 2006.

Attachment A: Analysis Request

Rev. 5

Experiment Analysis Request Form

This form should be used to request analyses from the Experiment Design and Analysis (C660) department. Provide the completed form(s) to Dave Schoonen (David.Schoonen@inl.gov).

Requester Information

Requester Name Kevin Clayton Date 7/11/2013 Rev 0

Office Phone ( )526-4315 Cell ( )821-1029 E-mail kevin.clayton@inl.gov

Type of Analysis Being Requested As-Run

Comments

Project Information

Project Name EPRI Project Number 29584

Project/Experiment Manager Kevin Clayton

Office Phone ( )6-4315 Cell ( )821-1029 E-mail kevin.clayton@inl.gov

Experiment Information

Test Name EPRI-2 Loop 2A

Test Information

Test Location CFT Insertion Cycle 153B Final Discharge Cycle 4/13/2013 Duration 13 EFPD

Specific ATR Position(s) Loop 2A ATR Cycle(s): 153A

Backup Test Information

Is an Experiment Safety Analysis (ESA) author needed? Yes ☐ No ☒ Assigned
Request ESA author from ATR Experiment Engineering (Dave Schoonen). ESA Author David Reeder

Is this a fueled experiment? Yes ☐ No ☒ *If yes, complete "calculations for fueled test"s section.*

Experiment References Used to Support Calculation & Analysis

Engineering Inputs

Experiment Plans

Experiment Design

T&FR

Drawings

ESA

ECAR

TEV

Emails/Letters

As-Built Data

Quality Level 3 Quality Level Database Number

CUI Information

Other

Provide the references listed above if they are not readily available through EDMS or other publicly available resources.

Rev. 5

Experiment Analysis Request Form

Neutronics/Physics Calculation & Analysis Request Form

Neutronics Analysis Request

Requesting a neutronics/physics analysis? Yes ☒ No☐ *If yes, please fill out the information on this page.*

Deliverable ECAR Deliverable Title EPRI-2 As-Run Analysis in Cycle 153B

Draft Due Date ______ Final/Approved Due Date 7/11/2013 Charge Number ______

Comments ______

Purpose of Analysis As-Run Physics and Source Term Analysis

Persons assigned to support calculation & analysis tasks (as applicable).

Performer/Author	J. W. Nielsen
Checker	Chris Glass
Independent Peer Reviewer	
Approver (Line Manager)	Dave Schoonen
Nuclear Safety Engineering	N/A
Acceptance (Owner)	Kevin Clayton
Other(s)	

Calculated Parameter	Scoping	Design	Projection	As-Run
Calculations for All Tests (typically required to support ESA)				
Neutron Heating Rates W/g ____	☐	☐	☐	☒
Gamma Heating Rates W/g ____	☐	☐	☐	☒
Test Reactivity Worth ($) relative to Water-Filled	☐	☐	☐	☐
Backup Test Reactivity Worth ($) relative to Water-Filled	☐	☐	☐	☐
Axial Flux Profile (FE(s) and coolant channel(s)?) ____	☐	☐	☐	☐
Other ____	☐	☐	☐	☐
Calculations for Tests in Flux Traps (typically required to support ESA)				
Temperature Coefficient of PCS (Flux Traps only) ($/°F)	☐	☐	☐	☐
Other ____	☐	☐	☐	☐
Additional Calculations for All Tests (not necessarily required to support ESA)				
Activation Ci Irradiation Time ____ days	☐	☐	☐	☒
Decay Heat W Cooling Time ____ days	☐	☐	☐	☒
DPA	☐	☐	☐	☐
Other Flux and Fluence	☐	☐	☐	☒
Calculations for Fueled Tests (not necessarily required to support ESA)				
Fuel Burnup ____	☐	☐	☐	☐
Fission Heating ____ Fission Density ____	☐	☐	☐	☐
Flux ____ (Fast/Thermal) ____	☐	☐	☐	☐
Fluence ____ (Fast/Thermal) ____	☐	☐	☐	☐
Fission Products ____	☐	☐	☐	☐
Local- or Point-to-Average Ratios ____	☐	☐	☐	☐
Other ____	☐	☐	☐	☐

Attachment B: ATR Power History for Cycle 153B

INTEROFFICE MEMORANDUM

Idaho National Laboratory

Date: April 22, 2013

To: R. A. Jordan

From: D. E. Hale

Subject: ADVANCED TEST REACTOR (ATR) POWER HISTORY THROUGH CYCLE 153A/B-1

References:
(a) A. V. Briscoe letter to J. L. Durney, AVB-9-77, ATR Power History Through Cycle 34C-1, June 7, 1977
(b) C. C. Swanson letter to J. L. Durney, CAS-05-86, ATR Power History Through Cycle 72A-1, February 3, 1986
(c) L. S. Loret letter to E. C. Anderson, Sr., LSL-11-94, ATR Power History Through Cycle 102B-1, February 28, 1994
(d) D. E. Hale letter to J. C. Chapman, DEH-05-04, Advanced Test Reactor (ATR) Power History Through Cycle 133B-1, August 18, 2004

Table 1 lists the ATR N-16 constrained power history data since the Beryllium VI Core Internals Changeout (Cycle 134A-1) through Cycle 153A/B-1. The ATR power history prior to Cycle 134A-1 is presented in the references.

Table 2 lists the accumulated N-16 total lobe MWd and total core MWd as obtained from the ATR DAS for Cycle 134A-1 through 153A/B-1.

DEH

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TABLE 1
SUMMARY OF ATR POWER HISTORY

Cycle	N-16 Average Lobe Powers (MW)					N-16 Lobe MWd						
No.	NW	NE	C	SW	SE	NW	NE	C	SW	SE	Total	EFPD
134A-1	----	----	----	----	----	0	0	0	0	0	0	----
134A-2	----	----	----	----	----	0.2	0.3	0.4	0.4	0.4	2.0	----
						0.2	0.3	0.4	0.4	0.4	2.0	
134B-1	18.0	18.0	24.5	23.0	25.0	452.8	452.2	615.5	578.5	628.6	2727.6	25.1
134B-2	18.0	18.0	25.8	23.0	25.0	385.6	385.8	553.5	493.2	536.1	2354.2	21.4
						838.4	838.0	1169.0	1071.7	1164.7	5081.8	46.5
135A-1	18.0	18.0	29.8	28.1	35.4	236.2	236.0	391.1	368.6	464.0	1695.8	13.1
135B-1	18.0	18.0	24.8	23.0	25.0	458.3	458.4	630.8	585.3	636.5	2769.2	25.5
135B-2	18.0	18.0	25.2	23.0	25.0	405.0	405.7	567.4	517.8	563.0	2458.9	22.5
						863.3	864.1	1198.2	1103.1	1199.5	5228.1	48.0
135C-1	18.0	18.0	25.0	23.0	25.0	729.9	729.7	1013.5	933.0	1013.9	4419.9	40.6
136A-1	18.0	18.0	24.0	23.0	23.0	916.2	916.4	1218.9	1169.5	1170.2	5391.1	50.9
136B-1	18.0	18.0	23.9	23.0	23.0	701.9	702.3	931.2	896.9	897.0	4129.4	39.0
137A-1	18.0	18.0	24.7	20.0	25.0	975.4	974.8	1336.2	1083.2	1353.3	5722.8	54.1
137B-1	20.0	17.9	35.5	56.6	30.4	242.0	217.0	429.6	685.4	367.6	1941.6	12.1
138A-1	18.0	18.0	23.6	23.0	25.0	1046.9	1047.7	1370.7	1336.4	1453.5	6255.1	58.1
138B-1	18.0	18.0	23.3	23.0	25.0	838.5	839.6	1084.8	1070.9	1164.6	4998.5	46.6
139A-1	18.0	18.0	23.9	23.0	25.0	928.7	929.1	1231.1	1186.3	1289.5	5564.6	51.6
139B-1	18.0	18.0	23.2	23.0	23.0	919.7	919.7	1187.5	1174.9	1175.0	5376.8	51.1
140A-1	18.0	18.0	21.8	23.0	23.0	837.0	837.2	1012.9	1069.7	1069.4	4826.1	46.5
140B-1	18.0	17.7	21.8	23.6	23.0	641.7	629.5	777.2	842.9	820.0	3711.3	35.7
141A-1	18.0	18.0	23.4	23.0	23.0	583.3	583.1	756.8	745.1	745.5	3413.7	32.4
142A-1	23.0	18.0	24.7	24.8	23.0	1104.9	864.8	1186.0	1192.5	1104.0	5452.2	48.0
142B-1	23.0	18.0	25.4	25.4	25.0	1196.9	936.7	1323.4	1322.5	1298.7	6078.2	52.0
143A-1/2	18.0	18.0	24.3	26.9	25.0	880.0	882.5	1187.7	1315.4	1223.1	5488.7	48.9
143B-1	18.0	18.0	24.9	27.0	25.1	1032.1	1032.6	1423.5	1543.7	1435.0	6466.9	57.3
144A-1	18.0	18.0	23.1	23.0	25.1	787.0	787.0	1006.7	1004.5	1093.4	4678.6	43.7
144B-1	18.0	18.1	22.4	23.0	23.0	932.3	933.4	1155.7	1190.7	1190.9	5403.0	51.7

TABLE 1
SUMMARY OF ATR POWER HISTORY

Cycle No.	N-16 Average Lobe Powers (MW) NW	NE	C	SW	SE	N-16 Lobe MWd NW	NE	C	SW	SE	Total	EFPD
145A-1	18.0	17.9	23.2	23.8	25.7	983.0	980.9	1267.3	1299.5	1407.8	5938.4	54.7
145B-1	17.8	17.8	23.0	24.6	25.8	1020.5	1020.0	1321.4	1407.8	1478.3	6247.9	57.3
146A-1	18.0	18.0	24.3	25.8	26.0	906.8	906.8	1225.7	1300.0	1312.6	5651.9	50.5
146B-1	23.0	18.0	26.0	23.0	26.0	903.7	707.1	1021.6	903.9	1021.0	4557.2	39.2
147A-1	23.0	18.0	24.1	20.9	23.0	1156.9	904.4	1208.4	1049.4	1155.2	5474.3	50.2
148A-1	18.0	18.0	23.6	22.0	23.0	856.0	855.8	1121.4	1043.8	1093.6	4970.6	47.5
148B-1	18.0	18.0	23.0	23.8	23.0	927.5	926.7	1181.6	1224.0	1185.0	5444.8	51.5
149A-1	18.0	18.0	24.2	24.0	23.0	662.5	662.7	891.3	883.3	846.8	3946.5	36.8
149B-1	18.0	18.0	24.2	23.0	23.0	964.4	964.5	1297.8	1231.6	1230.8	5689.0	53.6
150A-1	18.9	18.0	30.5	37.5	35.1	233.4	221.6	375.9	462.7	432.6	1726.2	12.3
150B-1	19.9	18.0	24.2	23.0	23.1	832.8	754.7	1014.6	964.9	966.0	4533.0	41.9
151A-1	18.9	14.2	22.0	23.6	23.0	1058.6	800.0	1237.0	1324.4	1289.0	5709.0	56.1
151B-1/2	18.9	14.5	22.1	23.0	23.0	971.4	741.8	1134.9	1181.9	1180.0	5209.9	51.3
152A-1/6	----	----	----	----	----	0.3	0.3	0.5	0.4	0.5	2	----
152B-1	18.9	15.9	22.4	23.0	23.0	966.4	813.0	1141.3	1172.1	1173.6	5266.4	51.0
153A/B-1	19.7	19.7	30.8	35.4	44.0	265.2	265.4	414.5	476.1	591.4	2012.6	13.45

TABLE 2
SUMMARY OF ACCUMULATED N-16 MWd

Cycle No.	Lobe NW	NE	C	SW	SE	Total MWd
134A-1	0	0	0	0	0	0
134A-2	0.2	0.3	0.4	0.4	0.4	2.0
134B-1	453.0	452.5	615.9	578.9	629.0	2729.6
134B-2	838.6	838.3	1169.4	1072.1	1165.1	5083.8
135A-1	1074.8	1074.3	1560.4	1440.8	1629.0	6779.7
135B-1	1533.1	1532.7	2191.2	2026.0	2265.5	9548.9
135B-2	1938.1	1938.4	2758.6	2543.8	2828.5	12007.8
135C-1	2668.0	2668.1	3772.1	3476.8	3842.4	16427.7
136A-1	3584.2	3584.5	4991.0	4646.3	5012.6	21818.8
136B-1	4286.1	4286.8	5922.2	5543.2	5909.5	25948.2
137A-1	5261.5	5261.6	7258.3	6626.4	7262.8	31670.9
137B-1	5503.5	5478.6	7687.9	7311.8	7630.5	33612.5
138A-1	6550.3	6526.3	9058.6	8648.2	9083.9	39867.7
138B-1	7388.9	7365.9	10143.4	9719.2	10248.6	44866.2
139A-1	8317.6	8295.0	11374.5	10905.4	11538.1	50430.8
139B-1	9237.3	9214.6	12562.0	12080.3	12713.1	55807.6
140A-1	10074.3	10051.8	13574.9	13150.0	13782.5	60633.7
140B-1	10716.0	10681.3	14352.1	13992.9	14602.5	64345.0
141A-1	11299.3	11264.4	15108.9	14737.9	15347.9	67758.6
142A-1	12404.2	12129.1	16294.9	15930.4	16452.0	73210.9
142B-1	13601.1	13065.8	17618.4	17252.8	17750.7	79289.0
143A-1/2	14481.1	13948.3	18806.0	18568.3	18973.7	84777.7
143B-1	15513.1	14980.9	20229.6	20112.0	20408.8	91244.7

TABLE 2 (Continued)
SUMMARY OF ACCUMULATED N-16 MWd

Cycle No.	Lobe NW	NE	C	SW	SE	Total MWd
144A-1	16300.1	15767.9	21236.2	21116.6	21502.2	95923.3
144B-1	17232.4	16701.4	22392.0	22307.3	22693.1	101326.3
145A-1	18215.3	17682.2	23659.3	23606.8	24100.8	107264.8
145B-1	19235.8	18702.2	24980.7	25014.6	25579.1	113512.6
146A-1	20142.5	19609.0	26206.5	26314.6	26891.6	119164.5
146B-1	21046.2	20316.1	27228.1	27218.4	27912.6	123721.7
147A-1	22203.1	21220.5	28436.5	28267.8	29067.7	129196.0
148A-1	23059.1	22076.3	29557.9	29311.6	30161.4	134166.5
148B-1	23986.6	23003.0	30739.5	30535.6	31346.4	139611.4
149A-1	24649.0	23665.7	31630.8	31418.9	32193.2	143557.8
149B-1	25613.4	24630.1	32928.6	32650.5	33424.0	149246.8
150A-1	25846.8	24851.7	33304.5	33113.2	33856.6	150973.1
150B-1	26679.6	25606.4	34319.1	34078.1	34822.6	155506.1
151A-1	27738.3	26406.4	35556.1	35402.5	36111.6	161215.1
151B-1/2	28709.7	27148.1	36690.9	36584.4	37291.6	166425.0
152A1/6	28710.0	27148.4	36691.4	36584.8	37292.1	166427.0
152B-1	29676.4	27961.4	37832.7	37756.9	38465.7	171693.4
153A/B-1	29941.6	28226.8	38247.2	38233.0	39057.1	173705.9

Attachment C: Material Compositions

ATI Wah Chang Zirconium Alloy Zircaloy-4

Categories: Metal; Nonferrous Metal; Zirconium Alloy

Material Notes: Zirconium resists corrosive attack in most organic and mineral acids, strong alkalis, and some molten salts. A tightly adherent and protective oxide film protects the metal-oxide interface to provide corrosion resistance. An additional benefit for zirconium alloys in long-term geological disposal options is the inert nature of zirconium oxide.

Information provided by ATI Wah Chang

Key Words: UNS R60804

Vendors: No vendors are listed for this material. Please click here if you are a supplier and would like information on how to add your listing to this material.

Physical Properties	Metric	English	Comments
Density	6.56 g/cc	0.237 lb/in³	

Mechanical Properties	Metric	English	Comments
Hardness, Rockwell B	89	89	
Tensile Strength, Ultimate	514 MPa	74600 psi	Room Temperature, Transverse
	541 MPa	78400 psi	Room Temperature, Longitudinal
	241 MPa @Temperature 288 °C	34900 psi @Temperature 550 °F	Transverse
	271 MPa @Temperature 288 °C	39300 psi @Temperature 550 °F	Longitudinal
Tensile Strength, Yield	381 MPa	55200 psi	Room Temperature, Longitudinal
	467 MPa	67800 psi	Room Temperature, Transverse
	152 MPa @Temperature 288 °C	22000 psi @Temperature 550 °F	Longitudinal
	177 MPa @Temperature 288 °C	25600 psi @Temperature 550 °F	Transverse
Modulus of Elasticity	99.3 GPa	14400 ksi	
Poissons Ratio	0.370	0.370	
Shear Modulus	36.19 GPa	5249 ksi	

Thermal Properties	Metric	English	Comments
CTE, linear	6.00 µm/m-°C @Temperature 20.0 °C	3.33 µin/in-°F @Temperature 68.0 °F	
Thermal Conductivity	21.5 W/m-K	149 BTU-in/hr-ft²-°F	
Melting Point	1850 °C	3360 °F	

Component Elements Properties	Metric	English	Comments
Chromium, Cr	0.070 - 0.13 %	0.070 - 0.13 %	
Fe + Cr	0.280 - 0.370 %	0.280 - 0.370 %	
Iron, Fe	0.18 - 0.240 %	0.18 - 0.240 %	
Tin, Sn	1.20 - 1.70 %	1.20 - 1.70 %	
Zirconium, Zr	97.56 - 98.27 %	97.56 - 98.27 %	

High Performance Stainless takes the gall

HPA ALLOYS

Nitronic 60

January 2009 Volume 1, Issue 3

Nitronic 60 is truly an all purpose metal. This fully austenitic alloy performs well as a high temperature alloy for temperatures around 1800°F. The oxidation resistance of Nitronic 60 is similar to Type 309 S.S., and far superior to Type 304S.S.

The additions of silicon and manganese have given the alloy a matrix to inhibit wear, galling, and fretting even in the annealed condition. Higher strengths are attainable through cold working the material and is still fully austenitic after severe cold-working. This working does not enhance the anti-galling properties as is normal for carbon steels and some stainless steels. The benefit to the cold or hot work put into the material is added strength and hardness.

The chromium and nickel additions give it comparable corrosion to 304 and 316 stainless steels, while having a twice the yield strengths of regular stainless steels. The high mechanical strength in annealed parts permits use of reduced cross sections for weight and cost reductions.

Several data sheets are available on the wear compatiblity of this alloy with dissimilar couples, as well as self-mated coupled results.

If your galling problem occurs at less than 1500°F, then you should think about switching to a more economical alloy. Nitronic 60 has a better cost advantage than any other alloy available. Other materials require an additional amount of heat treating to raise their hardness, where NITRONIC 60 is excellent in the annealed condition.

Properties & General Data

Nominal Chemistry

Cr	Ni	Mn	Si	N	Fe
17	8	8.0	4	0.14	Bal.

Mechanical Requirements

Properties	UTS	0.2% YS	Elon.	R/A	Hardness
Minimum	(Ksi)	(Ksi)	(%)	(%)	(Rockwell)
Annealed	95-105	50-55	35	55	B 95
These are minimum values for annealed bars up to and over 0.5" Diameter through 12" Bar.					

Specification levels for strain hardened bar

HPA Strength Level	UTS (KSI) Min.	YS (KSI) Min.	Elon. (%) Min.	R/A (%) Min.	Dia Range (Inclusive)
Level 1	110	90	35	55	0.125" - 4"
Level 2	135	105	20	50	0.125" - 4"
Level 3	160	130	15	45	0.125 - 3.5"
Level 4	180	145	12	45	0.062" - 2"
Level 5	200	180	10	45	0.062" - 1.5"

Questions?? Call (800)HPA-LLOY

Density 0.274 lb/in
Specific Gravity 7.62
Thermal Expansion Coefficient (68 to 212°F)
$8.8X10^{-6}$ in/in/Deg F
Electrical Resistivity (68°F)
589 Ohms/ cir mil ft
Tensile Modulus of Elasticity $26x10^{6}$ psi

High Performance Alloys, Inc.
444 Wilson St.
P.O. Box 40
Tipton, IN 46072
Tel (765)675-8871
Fax (765)675-7051

Any questions or comments can also be sent via E-Mail to:
Info@hpalloy.com
www.hpalloy.com

Stainless Steel - Grade 304 (UNS S30400)

Chemical Formula

Fe, <0.08% C, 17.5-20% Cr, 8-11% Ni, <2% Mn, <1% Si, <0.045% P, <0.03% S

Topics Covered

Background

Grade 304 is the standard "18/8" stainless; it is the most versatile and most widely used stainless steel, available in a wider range of products, forms and finishes than any other. It has excellent forming and welding characteristics. The balanced austenitic structure of Grade 304 enables it to be severely deep drawn without intermediate annealing, which has made this grade dominant in the manufacture of drawn stainless parts such as sinks, hollow-ware and saucepans. For these applications it is common to use special "304DDQ" (Deep Drawing Quality) variants. Grade 304 is readily brake or roll formed into a variety of components for applications in the industrial, architectural, and transportation fields. Grade 304 also has outstanding welding characteristics. Post-weld annealing is not required when welding thin sections.

Grade 304L, the low carbon version of 304, does not require post-weld annealing and so is extensively used in heavy gauge components (over about 6mm). Grade 304H with its higher carbon content finds application at elevated temperatures. The austenitic structure also gives these grades excellent toughness, even down to cryogenic temperatures.

Key Properties

These properties are specified for flat rolled product (plate, sheet and coil) in ASTM A240/A240M. Similar but not necessarily identical properties are specified for other products such as pipe and bar in their respective specifications.

Composition

Typical compositional ranges for grade 304 stainless steels are given in table 1.

Table 1. Composition ranges for 304 grade stainless steel

Grade		C	Mn	Si	P	S	Cr	Mo	Ni	N
304	min.	-	-	-	-	-	18.0	-	8.0	-
	max.	0.08	2.0	0.75	0.045	0.030	20.0		10.5	0.10
304L	min.	-	-	-	-	-	18.0	-	8.0	-
	max.	0.030	2.0	0.75	0.045	0.030	20.0		12.0	0.10
	min.	0.04	-	-		-	18.0		8.0	

304H					-0.045			-		-
	max.	0.10	2.0	0.75		0.030	20.0		10.5	

Mechanical Properties

Typical mechanical properties for grade 304 stainless steels are given in table 2.

Table 2. Mechanical properties of 304 grade stainless steel

Grade	Tensile Strength (MPa) min	Yield Strength 0.2% Proof (MPa) min	Elongation (% in 50mm) min	Hardness Rockwell B (HR B) max	Brinell (HB) max
304	515	205	40	92	201
304L	485	170	40	92	201
304H	515	205	40	92	201
304H also has a requirement for a grain size of ASTM No 7 or coarser.					

Physical Properties

Typical physical properties for annealed grade 304 stainless steels are given in table 3.

Table 3. Physical properties of 304 grade stainless steel in the annealed condition

Grade	Density (kg/m^3)	Elastic Modulus (GPa)	Mean Coefficient of Thermal Expansion (mm/m/°C)			Thermal Conductivity (W/m.K)		Specific Heat 0-100°C (J/kg.K)	Electrical Resistivity (nW.m)
			0-100°C	0-315°C	0-538°C	at 100°C	at 500°C		
304/L/H	8000	193	17.2	17.8	18.4	16.2	21.5	500	720

Grade Specification Comparison

Approximate grade comparisons for 304 stainless steels are given in table 4.

Table 4. Grade specifications for 304 grade stainless steel

Grade	UNS No	Old British		Euronorm		Swedish SS	Japanese JIS
		BS	En	No	Name		
304	S30400	304S31	58E	1.4301	X5CrNi18-10	2332	SUS 304
304L	S30403	304S11	-	1.4306	X2CrNi19-11	2352	SUS 304L
304H	S30409	304S51	-	1.4948	X6CrNi18-11	-	-
These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.							

Possible Alternative Grades

Possible alternative grades to grade 304 stainless steels are given in table 5.

Table 5. Possible alternative grades to 304 grade stainless steel

Grade	Why it might be chosen instead of 304
301L	A higher work hardening rate grade is required for certain roll formed or stretch formed components.
302HQ	Lower work hardening rate is needed for cold forging of screws, bolts and rivets.
303	Higher machinability needed, and the lower corrosion resistance, formability and weldability are acceptable.

316	Higher resistance to pitting and crevice corrosion is required, in chloride environments
321	Better resistance to temperatures of around 600-900°C is needed...321 has higher hot strength.
3CR12	A lower cost is required, and the reduced corrosion resistance and resulting discolouration are acceptable.
430	A lower cost is required, and the reduced corrosion resistance and fabrication characteristics are acceptable.

Corrosion Resistance

Excellent in a wide range of atmospheric environments and many corrosive media. Subject to pitting and crevice corrosion in warm chloride environments, and to stress corrosion cracking above about 60°C. Considered resistant to potable water with up to about 200mg/L chlorides at ambient temperatures, reducing to about 150mg/L at 60°C.

Heat Resistance

Good oxidation resistance in intermittent service to 870°C and in continuous service to 925°C. Continuous use of 304 in the 425-860°C range is not recommended if subsequent aqueous corrosion resistance is important. Grade 304L is more resistant to carbide precipitation and can be heated into the above temperature range.

Grade 304H has higher strength at elevated temperatures so is often used for structural and pressure-containing applications at temperatures above about 500°C and up to about 800°C. 304H will become sensitised in the temperature range of 425-860°C; this is not a problem for high temperature applications, but will result in reduced aqueous corrosion resistance.

Heat Treatment

Solution Treatment (Annealing) - Heat to 1010-1120°C and cool rapidly. These grades cannot be hardened by thermal treatment.

Welding

Excellent weldability by all standard fusion methods, both with and without filler metals. AS 1554.6 pre-qualifies welding of 304 with Grade 308 and 304L with 308L rods or electrodes (and with their high silicon equivalents). Heavy welded sections in Grade 304 may require post-weld annealing for maximum corrosion resistance. This is not required for Grade 304L. Grade 321 may also be used as an alternative to 304 if heavy section welding is required and post-weld heat treatment is not possible.

Machining

A "Ugima" improved machinability version of grade 304 is available in bar products. "Ugima" machines significantly better than standard 304 or 304L, giving higher machining rates and lower tool wear in many operations.

Dual Certification

It is common for 304 and 304L to be stocked in "Dual Certified" form, particularly in plate and pipe. These items have chemical and mechanical properties complying with both 304 and 304L specifications. Such dual certified product does not meet 304H specifications and may be unacceptable for high temperature applications.

Applications

Typical applications include:

• Food processing equipment, particularly in beer brewing, milk processing & wine making.

- Kitchen benches, sinks, troughs, equipment and appliances
- Architectural panelling, railings & trim
- Chemical containers, including for transport
- Heat Exchangers
- Woven or welded screens for mining, quarrying & water filtration
- Threaded fasteners
- Springs

Source: Atlas Steels Australia

For more information on this source please visit Atlas Steels Australia

Date Added: Oct 23, 2001 | Updated: Feb 14, 2013

Nielsen, Joseph W <joseph.nielsen@inl.gov>

Fwd: EPRI Mass

Tyler, Craig R <craig.tyler@inl.gov> Tue, Jan 15, 2013 at 12:18 PM
To: Joseph W Nielsen <joseph.nielsen@inl.gov>

This should get you a good estimate of the masses. See PLN-3990 for how many of each type of package.
Let me know if I missed anything.

---------- Forwarded message ----------
From: **Whitehead, Larry M** <larry.whitehead@inl.gov>
Date: Tue, Jan 15, 2013 at 11:16 AM
Subject: EPRI Mass
To: Craig R Tyler <craig.tyler@inl.gov>

Craig,
Here are the values that you asked for.

2A Zirc Holder : 4.021 lb mass

2B Zirc Holder : 4.100 lb mass

2C Zirc Holder : 3.067 lb mass

2D Zirc Holder : 4.927 lb mass

EPRI XM-19 Specimen Package (Dwg. 603653): 300 SST: studs, washers, front plate = .0252 lb mass ,
Nitronic 60 backplate = .024 lb mass ,
XM-19 specimens (2) = .102 lb mass x 2 = .204 lbs.

EPRI XM-750 Specimen Package (Dwg. 603653): Same as above except with X-750 specimens
X-750 Specimens (2) = .107 lb mass x 2 = .214 lbs.

EPRI 300 series PBU Specimen Package (Dwg. 601546): 300 SST: studs, washers, front plate = .0252 lb mass , Nitronic 60 backplate = .024 lb mass ,
300 series SST PBU specimens (2) = .102 lb mass x 2 = .204 lbs.

Monitor package: All 300 SST: studs, washers, front plate = .252 lb mass , Nitronic 60 backplate = .024 lb mass ,
specimen blocks with screws (2) = .200 lb mass

Tensile Package (Dwg 601547): All 300 SST including screw = .503 lb mass.

--
Craig Tyler