ORNL/LTR-2018/508

Completion of the Irradiation of Silicon Carbide Cladding Tube Specimens in the High Flux Isotope Reactor

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May 2018

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

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Fusion & Materials for Nuclear Systems Division

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Work Package Manager: Kory Linton
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ACKNOWLEDGMENTS

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ACRONYMS

HFIR	High Flux Isotope Reactor
ORNL	Oak Ridge National Laboratory
LWR	Light-water reactors
PTP	Peripheral target position
DPA	Displacements per atom
LAMDA	Low Activation Materials Development and Analysis
PIE	Post-irradiation examination

EXECUTIVE SUMMARY

This document outlines the irradiation of silicon carbide cladding tube specimens in the High Flux Isotope Reactor at Oak Ridge National Laboratory. The cladding tube specimens consisted of monolithic, composite, and coated SiC specimens in order to test the effect of these various materials on the overall cladding performance during irradiation. A total of 18 specimens were irradiated for one cycle, with 9 specimens irradiated at low heat flux conditions and 9 specimens at high heat flux conditions. The specimens were inserted in cycle 475 in September 2017 and reached an average irradiation dose of approximately 2.6 dpa.

1. INTRODUCTION

Silicon carbide (SiC) is being considered as an alternative to zircaloy cladding in light water reactors (LWRs) due to its potential for superior performance during accident scenarios. Identified SiC material properties that may improve cladding behavior during accidents include a high temperature strength, oxidation resistance, and stability under irradiation [1,2]. However, there are still a number of challenges regarding validation of SiC as a cladding for LWRs. For example, recent studies show that SiC has a high temperature dependence on swelling, which may create complicated stress states and micro-cracking in the material during irradiation [3]. In addition, poor hydrothermal corrosion of SiC in water could be detrimental for cladding performance during normal reactor operation [4]. Coated SiC specimens and SiC composites are currently under investigation due to the potential of the coatings to mitigate these issues [5].

This report briefly describes the experimental test matrix and summarizes the successful irradiation of 18 coated and composite SiC cladding tube specimens in the High Flux Isotope Reactor (HFIR). Half of the specimens were irradiated with high heat flux conditions and the other half at low heat flux irradiation conditions.

2. EXPERIMENTAL TEST MATRIX

The experiment consisted of two different rabbit designs in order to isolate the effect of irradiation damage in the absense of a temperature gradient in the material. The high heat flux design is used to simulate LWR reactor conditions while the low heat flux design is used to eliminate the temperature gradient across the cladding. Three low heat flux rabbits and three high heat flux rabbits were irradiated to a target temperature of approximately 300-350°C. The irradiated specimens consisted of a collection of various SiC materials: monolithic, composite, and duplex coated samples.

2.1 LOW HEAT FLUX DESIGN

The low heat flux design contains three hollow SiC tube specimens backfilled with a helium-argon gas mixture, which maintains a minimal temperature gradient across the specimens. The three SiC specimens are separated by aluminum centering thimbles and a compression spring is used at the end to keep all of the samples held in place within the rabbit. Figure 1 shows a schematic of the low heat flux rabbit design. The monolithic SiC specimens act as the temperature monitor during the irradiation, removing the need for additional thermometry.

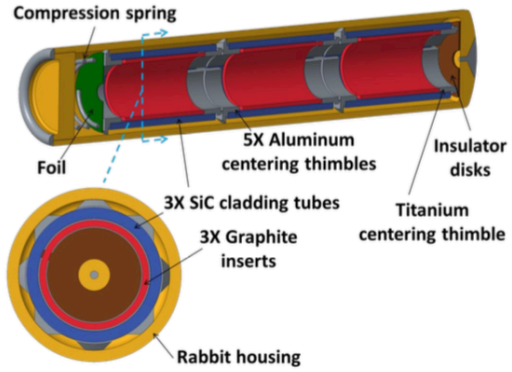

Figure 1. Schematic of design for rabbit used to irradiate silicon carbide tube specimens under low heat flux conditions [6].

2.2 HIGH HEAT FLUX DESIGN

The high heat flux design has a molybdenum heater located in the center of the samples. The heater drives the temperature gradient, simulating operating reactor cladding conditions. The outer surface of the sample is in contact with an aluminum sleeve surrounded by aluminum foil within the rabbit housing for adequate heat removal. The heat flux is approximately 0.66 MW/m^2 at the outer surface of the cladding [7]. Figure 2 shows a schematic of the high heat flux design. A SiC temperature monitor was located inside of the molybdenum tube to verify the temperatures reached during irradiation.

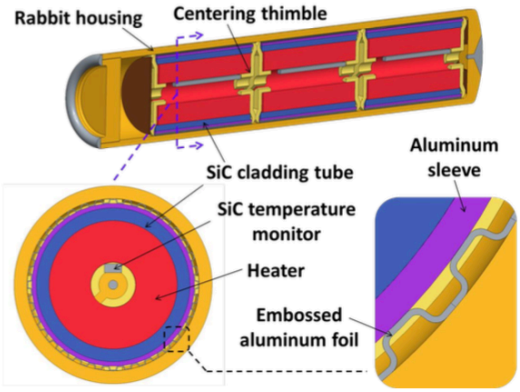

Figure 2. Schematic of rabbit design used to irradiate silicon carbide tube specimens under high heat flux conditions [6].

3. IRRADIATION IN HFIR

The 18 silicon carbide specimens were irradiated in HFIR for one cycle in September 2017. The specimens were put into peripheral target positions (PTP), with each specific rabbit location listed in Table 1. The target irradiation conditions included a fluence of 2.3 x 10^{21} - 2.4 x 10^{21} n/cm^2 and irradiation temperature of approximately 325°C at the surface of the specimen [6]. Additional documents regarding the insertion of the rabbits into HFIR are included in Appendix A.

Heat Flux	Rabbit	Sample ID	Core Position	SiC Material Type
Low	SCL01	CVD-L	A1-5	Monolithic
Low	SCL01	SA3-1	A1-5	Inner Composite, Outer Monolithic
Low	SCL01	N1N3(1)	A1-5	SiC/SiC Composite
Low	SCL05	CVD-Q	D1-5	Monolithic
Low	SCL05	6-RP-CR	D1-5	Inner Monolithic, Outer Composite
Low	SCL05	2-TM-CrN	D1-5	SiC/SiC Composite
Low	SCL06	CVD-R	G7-4	Monolithic
Low	SCL06	3-RP-CrN	G7-4	Inner Monolithic, Outer Composite
Low	SCL06	7-TM-TiN	G7-4	SiC/SiC Composite
High	ATFSC06	CVD-E	G4-4	Monolithic SiC
High	ATFSC06	GA-TGI-C-1	G4-4	SiC/SiC Composite
High	ATFSC06	N1N3(8)	G4-4	SiC/SiC Composite
High	ATFSC07	CVD-H	A1-4	Monolithic SiC
High	ATFSC07	TYPE S-1	A1-4	Inner Composite, Outer Monolithic
High	ATFSC07	SA3-2	A1-4	Inner Composite, Outer Monolithic
High	ATFSC09	CVD-G	A4-4	Monolithic SiC
High	ATFSC09	1-TM-CrN	A4-4	Inner Monolithic, Outer Composite
High	ATFSC09	4-RP-CrN	A4-4	SiC/SiC Composite

Table 1. Rabbit information and irradiation location for the SiC tube cladding specimens.

The irradiation dose during the cycle, measured in displacements per atom (dpa), was calculated for two SiC monolithic specimens using an online tool developed by Joseph Burns at ORNL. This tool calculates the evolution of dose and fluence during the irradiation of specimens in HFIR based on the material type and location in the reactor (http://jburns33.pythonanywhere.com/). The results for the progression of dose during irradiation of the two specimens were calculated using threshold displacement energies of 40 eV for silicon and 20 eV for carbon [8]. The total calculated accumulated dose for specimen CVD-L in rabbit SCL01 was 2.67 dpa (Figure 3) and the total accumulated dose for CVD-E specimen in ATFSC06 was 2.61 dpa (Figure 4). The doses are slightly different due to the different axial locations.

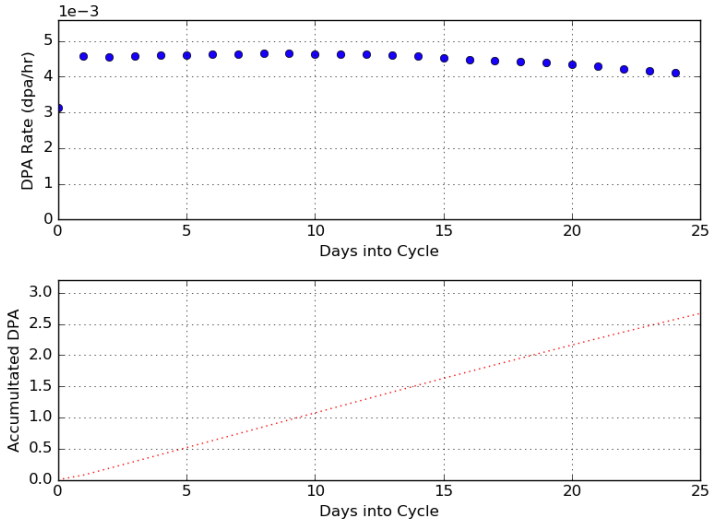

Figure 3. Plot of accumulated dpa throughout the irradiation cycle for the monolithic CVD-L (rabbit SCL01) sample located in peripheral target position A1 axial location 5, which reached a total dose of approximately 2.67 dpa.

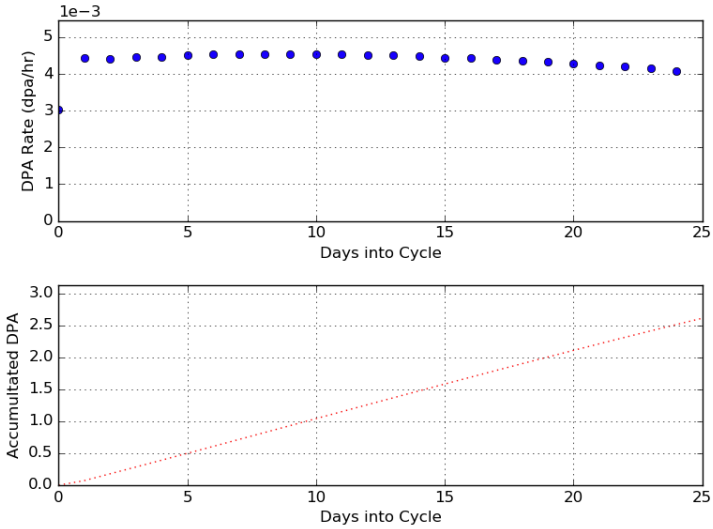

Figure 4. Plot of accumulated dpa throughout the irradiation cycle for the monolithic CVD-E (rabbit ATFSC06) sample located in peripheral target position G4 axial location 4, which reached a total dose of approximately 2.61 dpa.

4. CONCLUSION

Six rabbit capsules successfully completed irradiation in HFIR after one cycle in September 2017. This concluded the design, build and irradiation of protyopical and model SiC-based ATF SiC cladding under a high and low radial heat flux scope under the Nuclear Science User Faciltiy (NSUF) Work Package: UF-18OR020710 for fiscal year 2018. The capsule shipment, hotcell disassembly, and Low Activation Materials Development and Analysis (LAMDA) laboratory post-irradiation examination (PIE) are underway. An initial report of the shipments and disassembly under Work Package UF-18OR020711 will follow this report in September 2018 and LAMDA PIE will continue until the end of fiscal year 2019.

5. REFERENCES

1. Cheng, T., et al, "SiC oxidation in steam environments at elevated temperature and pressure," *Transactions of the American Nuclear Society*, 106 (2012) p. 1233-1234.
2. Ozawa, K., et al, "Cavity swelling behavior in SiC/SiC under charged particle irradiation," *Fusion Science and Technology*, 47 (2005) p. 871-875.
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4. Hirayama, H., et al, " Corrosion behavior of silicon carbide in 290C water," *Journal of American Ceramic Society*, 72 (1989) p. 2049-2053.
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7. Petrie, C.M., et al, "Experimental design and analysis for irradiation of SiC/SiC composite tubes under a prototypic high heat flux," *Journal of Nuclear Materials*, 491 (2017) p. 94-104.
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POOL WORK MANAGEMENT WORK PLAN (PWMWP)	REV. 22	PWPF-1200.1 Page 1 of 2

PREAPPROVALS (See Note)	Preparer	For FEM Transfers:	Date	HFIR Operations Manager	Date
	Greg Hirtz	RCT Notified: ☐Yes ☑N/A MBA Notified: ☐Yes ☑N/A	8/17/17	Brian E Fuller	8/18/2017

Note: Preapproval signatures certify that the requested activities result in a HFIR configuration consistent with one of those established in EG-2.

Previous PWMWP	Current PWMWP
NA	Cycle 475-1

SUPPORT DOCUMENTS	Document	DHSS Initials	Date	Applicability
	Approved EABD (Section 6 ONLY) attached (see EG-1).	DS	8/16/17	Required ONLY if installing an experiment into the reactor or a fuel-storage array. Otherwise N/A.
	Approved PTWS attached (see PWPF-1167.1).	DS	8/16/17	Required ONLY if reconfiguring a peripheral-target rabbit using a referenced PTWS. Otherwise N/A.
	Approved TBWS attached (see PWPF-1169.1).	DS	8/16/17	Required ONLY if reconfiguring a target-bundle component (exclusive of a peripheral-target rabbit) using a referenced TBWS. Otherwise N/A.
	Approved TRRHWS attached (see PWPF-1168.1)	DS	8/20/17	Required ONLY if reconfiguring the loading of a target rod rabbit holder using a referenced TRRHWS. Otherwise N/A.
	Applicable Lift Plan(s) Approved	DS	8/20/17	Required ONLY if any of the requested lift(s) have **NOT** been classified as manual. Otherwise N/A.

EABD = Experiment Authorization Bases Document, PTWS = Peripheral-Target Work Schedule, TBWS = Target-Bundle Work Schedule, TRRHWS = Target Rod Rabbit Holder Work Schedule.

POOL-WORK SUBMODE	Condition	DHSS Initials	Date	Applicability
	NOT required.	N/A	N/A	Pool-Work Submode required ONLY if any activity requested on this PWMWP involves the handling of an irradiated experiment (including irradiated rabbits) or a hoisting/rigging activity in/over the clean pool. If required, Pool-Work Submode shall be maintained for the entire PWMWP.
	Required AND established per PWP-1010.	BW/JMR	8/16/17

	Component Identifier (see Note 1)	Governing Instructions (see Note 2)	Lift Classification		Tool Identifier	Tool-Locking Verification		Submerged Weight (lb)		Source	Destination	Completion Verification	
			Type	DHSS Initials		Key Word	DHSS Initials	Expected	Actual			DHSS Initials	Confirm Initials
1	Target bundle	PWP-1169	Pre-eng	DS	UTN-06	13cw	DS	50	45	Target storage stand	Target work platform	DS	MW
2	*Target Rods*	PWP-1168	NA	NA	NA	NA	NA	NA	NA	Carousel platform	Completion of TRRHWS ident. '475-1' thru '475-11'	MW	
3	Target bundle	PWP-1169	Preeng	JMR	UTN-06	13cw	JMR	50	50	Target work platform	PTP work platform	JMR	
4	*PTP Rods*	PWP-1167	NA	NA	NA	NA	NA	NA	NA	Carousel platform	Completion of PTWS ident. '475-12' thru '475-17'	JMR	
5	Target bundle	PWP-1169	NA	NA	NA	NA	NA	NA	NA	PTP work platform	Complete Target bundle "Cycle 475"	JMR	
6	Target bundle	PWP-1169	Pre-eng	JMR	UTN-06	13cw JMR	JMR	50	50	PTP work platform	Target storage stand	JMR	
7													
8													

DHSS = Directing HFIR Shift Supervisor, MWP = Maintenance Work Package, PWP = Pool Work Procedure, TXP = Transportation Procedure

Note 1: The movement of a hydraulic-tube rabbit is NOT governed by a PWMWP. Note 2: Typically reference a specific MWP, PWP, PTWS, TBWS, TXP, etc.

COMMENTS	This instruction directs the completion of target bundle work for SOC 475. There are two new target holder rods identified in brief as '16-01' and '16-02' (paperwork for SN 2016-01 and 2016-02 is attached).
	There are 24 new rabbits; 5 SE rabbits (Se-237 etc.), 7 ATFSC0# rabbits, 4 FHC0# rabbits, 6 SCL0# rabbits, and 2 SSM2# rabbits addressed in the five attached EABDs.

TARGET BUNDLE WORK SCHEDULE	REV. 11	PWPF-1169.1 Page 1 of 2

Resultant Target Bundle loading configuration reviewed for compliance with EG-2 "Cycle 475" Approved Mary Todd Date 8/17/17

Markings on dummy target rods may not be legible. Indicate any differences from indicated designation

	MOVE SEQ. NO.	UNIT NO.	SOURCE	RECEIVER	DHSS Initial	Confirm Initial
PL1	10	08-05	**B-1**	Platform	DH	
	11	08-05	Platform	**B-1**	DH	MW
	12	D-16	**D-3**	Sto L 7	DH	
	13	16-01	Platform	**D-3**	DH	MW
			E-2			
				E-2		
			G-5			
				G-5		
			E-5			
				E-5		
			F-7			
				F-7		
			C-6			
				C-6		
			C-4			
				C-4		
			A-3			
				A-3		
PL2	14	08-15	**A-2**	Platform	DH	
	15	08-15	Platform	**A-2**	DH	MW
			C-3			
				C-3		
	16	08-06	**C-1**	Platform	MA	
	17	08-06	Platform	**C-1**	MA	bg
			F-3			
				F-3		
			E-4			
				E-4		
			G-6			
				G-6		
	18	08-13	**E-7**	Platform	MA	
	19	16-02	Platform	**E-7**	MA	MA
	20	08-24	**D-5**	Platform	MA	
	21	08-24	Platform	**D-5**	MA	MA
			B-5			
				B-5		
	Last (36)	**Completion Date** 8/21/17				

	MOVE SEQ. NO.	UNIT NO.	SOURCE	RECEIVER	DHSS Initial	Confirm Initial
PL3			**B-4**			
				B-4		
			B-2			
				B-2		
	2	08-17	**D-2**	Platform	DH	
	3	08-17	Platform	**D-2**	DH	MW
	4	08-19	**F-4**	Platform	DH	
	5	08-19	Platform	**F-4**	DH	MW
			F-6			
				F-6		
	6	08-01	**D-4**	Platform	DH	
	7	08-01	Platform	**D-4**	DH	MW
	8	08-23	**D-6**	Platform	DH	
	9	08-23	Platform	**D-6**	DH	MW
PL4	24	*Dum* 88-5	**B-3**	Sto K-1	MA	
	1	*Dum* 88-5	Sto K-1	**B-3 ***	DH	MW
	22	08-10	**C-2**	Platform	MA	
	23	08-10	Platform	**C-2**	MA	bg
			E-3			
				E-3 *		
			F-5			
				F-5		
			E-6			
				E-6 *		
			C-5			
				C-5		
PTP	25	11-08	**A-1**	Platform	MA	
	26	11-08	Platform	**A-1**	MA	MA
	27	11-12	**D-1**	Platform	MA	
	28	11-12	Platform	**D-1**	MA	bg
	29	11-09	**G-4**	Platform	MA	
	30	11-09	Platform	**G-4**	MA	bg
	31	11-03	**G-7**	Platform	MA	
	32	11-03	Platform	**G-7**	MA	MA
	33	11-04	**D-7**	Platform	MA	
	34	11-04	Platform	**D-7**	MA	MA
	35	11-14	**A-4**	Platform	MA	
	36	11-14	Platform	**A-4**	MA	MA

*Solid dummy target rods are only allowed into the "Receiver" marked.

☒ NO METS work --- Page 2 **NOT** included.

Storage Rack/Position = "STO-XX"

Issue Date: 5/02/2007

WORK COPY

PERIPHERAL TARGET WORK SCHEDULE (PTWS)	REV. 11	PWPF-1167.1 Page 1 of 1

The changes to starting configuration and resulting ending configuration were reviewed and meet the limits below:

☐ Ending Rabbit Configuration is adequately cooled under 130% reactor overpower conditions.
Reference Calculation: C-HFIR-2001-026, C-HFIR-2003-040, C-HFIR-2004-060, C-HFIR-2015-019, C-HFIR-2016-041, C-HFIR-2017-003

☐ Ending Rabbit Configuration is adequately cooled under reactor transient conditions associated with LOOP **AND** SBLOCA accidents. Reference Calculation: C-HFIR-2001-026 (C-HFIR-2017-002)

☐ Ending Rabbit Configuration is adequately cooled under a 50% reduced flow condition.
Reference Calculation: C-HFIR-2001-026 (C-HFIR-2017-002)

Prepared/Approved by: _____ RRD Exp. and Fab. Interface — 8/17/17 Date

Reviewed/Approved by: _____ RRD Exp. and Fab. Interface OR RRD Safety Analyst — 8/17/2017 Date

Starting Configuration for: 11-08 Identifier: 475 - 12

End plug	Pos 1	Pos 2	Pos 3	Pos 4	Pos 5	Pos 6	Pos 7
	5-05-20	**S-87**	S-72	S-74	FCAB06	FCZ02	

Activity	Move #	Unit No. (s)	FROM	TO	DHSS initial	Confirm initial
Transfer	N/A	PTP-_11-08_	Target Bundle	PTP Unthreading Plate	MR	MR
Unload	N/A	Rabbits in PTP-_11-08__	PTP Unthreading Plate	Dump Tray	MR	MR
Store	N/A	FCAB06	Dump tray	Sto Basket 'E'	MR	MR
	N/A	S-74	Dump tray	Sto Basket 'A'	MR	MR
	N/A					
	N/A					
	N/A					
	N/A					
	N/A					
Transfer	N/A	PTP-_11-08_w/ end plug	PTP Unthreading Plate	Loading station	MR	MR
Load	1			Position 7		
	2	FCZ02	Dump tray	Position 6	MR	MR
	3	SCL01	Pool side	Position 5	MR	MR
	4	ATFSC07	Pool side	Position 4	MR	MR
	5	S-72	Dump tray	Position 3	MR	MR
	6	S-87	Dump tray	Position 2	MR	MR
	7	5-05-20	Dump tray	Position 1	MR	MR
Transfer	N/A	PTP- 11-08 w/end plug	Loading station	Target Bundle	MR	

Ending Configuration for: 11-08

End plug	Pos 1	Pos 2	Pos 3	Pos 4	Pos 5	Pos 6	Pos 7
	5-05-20	S-87	S-72	**ATFSC07**	**SCL01**	FCZ02	

Comments on mechanical operation or appearance of the PTP rabbit holder:

PERIPHERAL TARGET WORK SCHEDULE (PTWS)	REV. 11	PWPF-1167.1 Page 1 of 1

The changes to starting configuration and resulting ending configuration were reviewed and meet the limits below:

☐ Ending Rabbit Configuration is adequately cooled under 130% reactor overpower conditions.
Reference Calculation: C-HFIR-2001-026, C-2003-040, C-HFIR-2004-060, C-HFIR-2016-041

☐ Ending Rabbit Configuration is adequately cooled under reactor transient conditions associated with LOOP **AND** SBLOCA accidents. Reference Calculation: C-HFIR-2001-026 (C-HFIR-2017-002)

☐ Ending Rabbit Configuration is adequately cooled under a 50% reduced flow condition.
Reference Calculation: C-HFIR-2001-026 (C-HFIR-2017-002)

Prepared/Approved by: _____ RRD Exp. and Fab. Interface — Date: 8/17/17

Reviewed/Approved by: _____ RRD Exp. and Fab. Interface OR RRD Safety Analyst — Date: 8/17/2017

Starting Configuration for: 11-12 Identifier: 475 - 13

End plug	Pos 1	Pos 2	Pos 3	Pos 4	Pos 5	Pos 6	Pos 7
	5-05-23	S-25	S-56	S-20	**S-53**	FCAB02	

Activity	Move #	Unit No. (s)	FROM	TO	DHSS initial	Confirm initial
Transfer	N/A	PTP-11-12	Target Bundle	PTP Unthreading Plate	MR	MR
Unload	N/A	Rabbits in PTP-11-12	PTP Unthreading Plate	Dump Tray	MR	MR
Store	N/A	FCAB02	Dump Tray	Sto Basket 'E'	MR	MR
	N/A	S-20	Dump Tray	Sto Basket 'A'	MR	MR
	N/A					
	N/A					
	N/A					
	N/A					
	N/A					
Transfer	N/A	PTP- 11-12 w/ end plug	PTP Unthreading Plate	Loading station	MR	MR
Load	1			Position 7		
	2	S-53	Dump Tray	Position 6	MR	MR
	3	SCL05	Pool side	Position 5	MR	MR
	4	SCL02	Pool side	Position 4	MR	MR
	5	S-56	Dump Tray	Position 3	MR	MR
	6	S-25	Dump Tray	Position 2	MR	MR
	7	5-05-23	Dump Tray	Position 1	MR	MR
Transfer	N/A	PTP- 11-12 w/end plug	Loading station	Target Bundle	MR	

Ending Configuration for: 11-12

End plug	Pos 1	Pos 2	Pos 3	Pos 4	Pos 5	Pos 6	Pos 7
	5-05-23	S-25	S-56	**SCL02**	**SCL05**	S-53	

Comments on mechanical operation or appearance of the PTP rabbit holder:

WORK COPY

PERIPHERAL TARGET WORK SCHEDULE (PTWS)	REV. 11	PWPF-1167.1 Page 1 of 1

The changes to starting configuration and resulting ending configuration were reviewed and meet the limits below:

☐ Ending Rabbit Configuration is adequately cooled under 130% reactor overpower conditions.
Reference Calculation: C-HFIR-2001-026, C-HFIR-2015-019, C-HFIR-2016-041

☐ Ending Rabbit Configuration is adequately cooled under reactor transient conditions associated with LOOP **AND** SBLOCA accidents. Reference Calculation: C-HFIR-2001-026

☐ Ending Rabbit Configuration is adequately cooled under a 50% reduced flow condition.
Reference Calculation: C-HFIR-2001-026

Prepared/Approved by: _____ RRD Exp. and Fab. Interface — Date: 8/17/17

Reviewed/Approved by: _____ RRD Exp. and Fab. Interface OR RRD Safety Analyst — Date: 8/17/2017

Starting Configuration for: 11-09 Identifier: 475 - 14

End plug	Pos 1	Pos 2	Pos 3	Pos 4	Pos 5	Pos 6	Pos 7
	S-78	S-54	S-3	S-62	**S-76**		

Activity	Move #	Unit No. (s)	FROM	TO	DHSS initial	Confirm initial
Transfer	N/A	PTP-11-09	Target Bundle	PTP Unthreading Plate	MR	fvg
Unload	N/A	Rabbits in PTP-11-09	PTP Unthreading Plate	Dump Tray	MR	fvg
Store	N/A	S-76	Dump Tray	Sto Basket 'A'	MR	fvg
	N/A					
	N/A					
	N/A					
	N/A					
	N/A					
	N/A					
Transfer	N/A	PTP- 11-09 w/ end plug	PTP Unthreading Plate	Loading station	MR	fvg
Load	1			Position 7		
	2	S-62	Dump Tray	Position 6	MR	fvg
	3	SCL03	Pool side	Position 5	MR	fvg
	4	ATFSC06	Pool side	Position 4	MR	fvg
	5	S-3	Dump Tray	Position 3	MR	fvg
	6	S-54	Dump Tray	Position 2	MR	fvg
	7	S-78	Dump Tray	Position 1	MR	fvg
Transfer	N/A	PTP- 11-09 w/end plug	Loading station	Target Bundle	MR	

Ending Configuration for: 11-09

End plug	Pos 1	Pos 2	Pos 3	Pos 4	Pos 5	Pos 6	Pos 7
	S-78	S-54	S-3	**ATFSC06**	**SCL03**	S-62	

Comments on mechanical operation or appearance of the PTP rabbit holder:

PERIPHERAL TARGET WORK SCHEDULE (PTWS)	REV. 11	PWPF-1167.1 Page 1 of 1

The changes to starting configuration and resulting ending configuration were reviewed and meet the limits below:

☐ Ending Rabbit Configuration is adequately cooled under 130% reactor overpower conditions.
Reference Calculation: C-HFIR-2001-026, C-HFIR-2008-045, C-HFIR-2016-041

☐ Ending Rabbit Configuration is adequately cooled under reactor transient conditions associated with LOOP **AND** SBLOCA accidents. Reference Calculation: C-HFIR-2001-026

☐ Ending Rabbit Configuration is adequately cooled under a 50% reduced flow condition.
Reference Calculation: C-HFIR-2001-026

Prepared/Approved by: _____ RRD Exp. and Fab. Interface — Date: 8/17/17

Reviewed/Approved by: _____ RRD Exp. and Fab. Interface OR RRD Safety Analyst — Date: 8/17/2017

Starting Configuration for: 11-03 Identifier: 475 - 15

End plug	Pos 1	Pos 2	Pos 3	Pos 4	Pos 5	Pos 6	Pos 7
	S-1	S-69	S-9	S-52	**FCAT07**	**FCAT08**	

Activity	Move #	Unit No. (s)	FROM	TO	DHSS initial	Confirm initial
Transfer	N/A	PTP-_11-03_	Target Bundle	PTP Unthreading Plate	MR	cy
Unload	N/A	Rabbits in PTP-_11-03__	PTP Unthreading Plate	Dump Tray	MR	cy
Store	N/A	S-52	Dump Tray	Sto Basket 'A'	MR	cy
	N/A		Dump Tray			
	N/A		Dump Tray			
	N/A		Dump Tray			
	N/A		Dump Tray			
	N/A		Dump Tray			
	N/A		Dump Tray			
Transfer	N/A	PTP-_11-03_w/ end plug	PTP Unthreading Plate	PTP Loading Station	MR	cy
Load	1		Dump tray	Position 7		
	2	FCAT08	Dump tray	Position 6	MR	cy
	3	FCAT07	Dump tray	Position 5	MR	cy
	4	SCL06	Pool side	Position 4	MR	cy
	5	S-9	Dump tray	Position 3	MR	cy
	6	S-69	Dump tray	Position 2	MR	cy
	7	S-1	Dump tray	Position 1	MR	cy
Transfer	N/A	PTP-11-03 w/end plug	Loading station	Target Bundle	MR	

Ending Configuration for: 11-03

End plug	Pos 1	Pos 2	Pos 3	Pos 4	Pos 5	Pos 6	Pos 7
	S-1	S-69	S-9	**SCL06**	FCAT07	FCAT08	

Comments on mechanical operation or appearance of the PTP rabbit holder:

PERIPHERAL TARGET WORK SCHEDULE (PTWS)	REV. 11	PWPF-1167.1 Page 1 of 1

The changes to starting configuration and resulting ending configuration were reviewed and meet the limits below:

☐ Ending Rabbit Configuration is adequately cooled under 130% reactor overpower conditions.
Reference Calculation: C-HFIR-2001-026, C-HFIR-2003-040, C-HFIR-2004-060, C-HFIR-2007-020, C-HFIR-2017-003

☐ Ending Rabbit Configuration is adequately cooled under reactor transient conditions associated with LOOP **AND** SBLOCA accidents. Reference Calculation: C-HFIR-2001-026

☐ Ending Rabbit Configuration is adequately cooled under a 50% reduced flow condition.
Reference Calculation: C-HFIR-2001-026

Prepared/Approved by: _____ RRD Exp. and Fab. Interface — Date: 8/17/17

Reviewed/Approved by: _____ RRD Exp. and Fab. Interface OR RRD Safety Analyst — Date: 8/17/2017

Starting Configuration for: 11-14 Identifier: 475-17

End plug	Pos 1	Pos 2	Pos 3	Pos 4	Pos 5	Pos 6	Pos 7
	S-17	5-05-24	S-86	FCAB04	**S-23**	FCZ05	

Activity	Move #	Unit No. (s)	FROM	TO	DHSS initial	Confirm initial
Transfer	N/A	PTP-11-14	Target Bundle	PTP Unthreading Plate	MR	MS
Unload	N/A	Rabbits in PTP-11-14	PTP Unthreading Plate	Dump Tray	MR	MS
Store	N/A	FCAB04	Dump Tray	Sto basket 'E'	MR	MS
	N/A	S-23	Dump Tray	Sto basket 'A'	MR	MS
	N/A					
	N/A					
	N/A					
	N/A					
	N/A					
Transfer	N/A	PTP- 11-14 w/ end plug	PTP Unthreading Plate	Loading station	MR	MS
Load	1			Position 7		
	2	FCZ05	Dump Tray	Position 6	MR	MS
	3	SCL04	Pool side	Position 5	MR	MS
	4	ATFSC09	Pool side	Position 4	MR	MS
	5	S-86	Dump Tray	Position 3	MR	MS
	6	5-05-24	Dump Tray	Position 2	MR	MS
	7	S-17	Dump Tray	Position 1	MR	MS
Transfer	N/A	PTP- 11-14 w/end plug	Loading station	Target Bundle	MR	

Ending Configuration for: 11-14

End plug	Pos 1	Pos 2	Pos 3	Pos 4	Pos 5	Pos 6	Pos 7
	S-17	5-05-24	S-86	**ATFSC09**	**SCL04**	FCZ05	

Comments on mechanical operation or appearance of the PTP rabbit holder:

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