ORNL/SPR-2019/1392

Assembly of Capsules for Irradiation of Silicon Carbide Joint Specimens in the High Flux Isotope Reactor

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November 2019

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

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Reactor and Nuclear Systems Division

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SUMMARY

This report provides a summary of the test matrix and assembly of thirteen capsules containing silicon carbide joint specimens, where the goal of this experiment is to investigate the effects of irradiation on such joints. Two capsule designs are used to accommodate two different specimen geometries: a small torsion specimen to measure basic thermomechanical properties, and a cladding-style "end plug" specimen to demonstrate the strength and integrity of such cladding under typical thermal gradients and stresses. The assembled capsules are scheduled for two cycles of irradiation in the flux trap of the High Flux Isotope Reactor with two different target temperatures: 350 and 750°C.

ACRONYMS AND ABBREVIATIONS

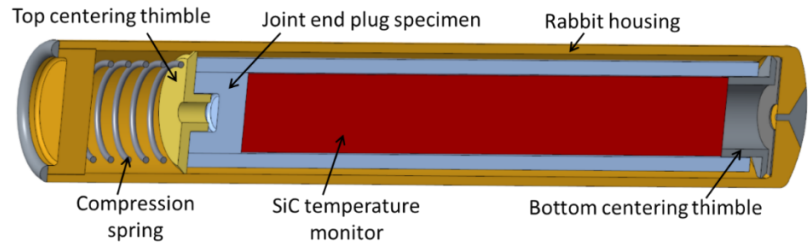
CVD	chemical vapor deposition
DOE	US Department of Energy
GA	General Atomics
HFIR	High Flux Isotope Reactor
ORNL	Oak Ridge National Laboratory
SiC	silicon carbide
TEP	transient eutectic phase

1. INTRODUCTION

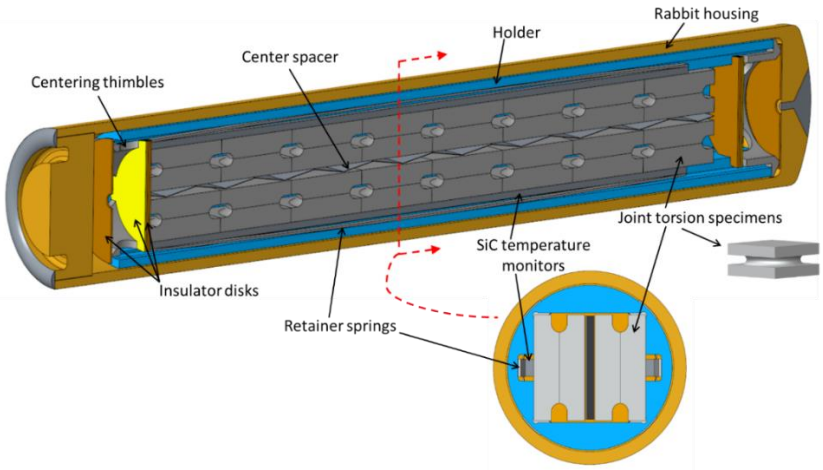
Silicon carbide (SiC) fiber reinforced SiC matrix composites (SiC-SiC) are of interest for fuel cladding and structural components in current and advanced nuclear reactor designs because of their strength retention at high temperature, high-temperature steam oxidation resistance, and stability under neutron irradiation [1]. However, to fabricate a complex geometry or to create a hermetic seal, SiC-based reactor components must be joined. While SiC performance under neutron irradiation is relatively well understood, the performance of the specific joining technologies has received much less attention to date. Any joint technology that will be deployed for in-core applications in current and advanced reactor designs must first demonstrate acceptable irradiation tolerance following irradiation in a materials test reactor.

General Atomics (GA) is currently investigating three joint variations: transient eutectic phase (TEP) SiC-based joints, oxide joints, and high purity SiC-based hybrid joints that use a preceramic polymer with chemical vapor deposition (CVD) SiC. Tube specimens with a single sealed end (i.e., end plug specimens) and torsion specimens have been fabricated using each of the three joint variations. The purpose of this project is to perform experimental irradiation testing of the joint specimens to understand the effects of irradiation with and without realistic temperature gradients, which can drive significant stress [2] [3] [4].

The SiC joint specimens will be inserted into the Oak Ridge National Laboratory (ORNL) High Flux Isotope Reactor (HFIR) using irradiation capsules, or rabbits, which are designed to achieve the desired specimen temperatures during irradiation. The experiment design concepts are detailed in Petrie et al. [5] and are shown in Figure 1. This report presents the irradiation test matrix and summarizes the assembly of thirteen rabbits containing SiC joint specimens.



(a)



(b)

Figure 1. Capsule design concepts for (a) the end plug specimens and (b) the torsion specimens.

2. TEST MATRIX

Table 1 summarizes the irradiation test matrix, including details on the irradiation conditions, capsule fill gases, and the specimens being inserted in the capsules. Capsule PGA01 through PGA11 accommodate one end plug specimen each, while capsules TGA01 and TGA02 accommodate sixteen torsion specimens each. This test matrix allows the irradiation of each specimen's geometry and each joint type at both target temperatures, 350 ± 50°C and 750 ± 50°C. All the capsules will be inserted in axial position 7 of a target rod rabbit holder in the HFIR flux trap for 2 cycles, corresponding to an approximate dose of 2 dpa. Position 7 is located at the top of the HFIR core, approximately 19.3 cm from the core's midplane.

Table 1. Irradiation test matrix

Capsule ID	Temperature (°C)	Fill gas	Joint type	Specimen ID
PGA01	350	He	Oxide	GC1
PGA02	350	He	Oxide	GC2
PGA03	750	46% He, Ar bal.	Oxide	GC3
PGA04	750	46% He, Ar bal.	Oxide	GC7
PGA05	350	He	Hybrid	HS3
PGA06	350	He	Hybrid	HS7
PGA07	750	46% He, Ar bal.	Hybrid	HS8
PGA08	750	46% He, Ar bal.	TEP	TE2
PGA09	750	46% He, Ar bal.	Hybrid	HS9
PGA10	750	46% He, Ar bal.	TEP	TE3
PGA11	350	He	TEP	TE9
TGA01	300	He	TEP Oxide Hybrid	1TE, 3TE, 5TE, 7TE, 9TE 1GC, 5GC, 10GC, 11GC, 15GC, 18GC 1HS, 5HS, 9HS, 11HS, 13HS
TGA02	800	Ar	TEP Oxide Hybrid	2TE, 4TE, 6TE, 8TE, 10TE, 11TE 4GC, 7GC, 16GC, 17GC, 20GC 2HS, 8HS, 14HS, 17HS,19HS

3. CAPSULE ASSEMBLY AND DELIVERY TO HFIR

3.1 TUBE SPECIMEN CAPSULE ASSEMBLY

Eleven capsules, with IDs PGA01 through PGA11 were assembled. A twelfth capsule was initially planned to be built as well, but the twelfth specimen (TE4) was damaged before assembly (see Figure 2). Each capsule contains one end plug specimen, and a single SiC rod is placed inside the specimen for passive temperature monitoring [6]. The complete parts layout is shown in Figure 3. Figure 4 shows a top-down view of the thermometry fitting inside an end plug specimen, with the specimen assembled inside the capsule housing. Housings were chosen so that the as-built end plug specimen-to-housing gas gap matches the desired 510 µm gap as closely as possible. Nine of the eleven capsules have as-built gas gaps within 10 µm (2%) of the nominal gap. Capsules PGA02 and PGA03 have slightly larger gaps, as large as 543 µm (6.4% larger than the nominal gap). The radiograph of a capsule in Figure 5 shows the different components assembled in the capsule.

Figure 2. Damaged end plug specimen.

PGA01

PGA02

PGA03

PGA04

Figure 3. Parts layout for capsules PGA01 through PGA11.

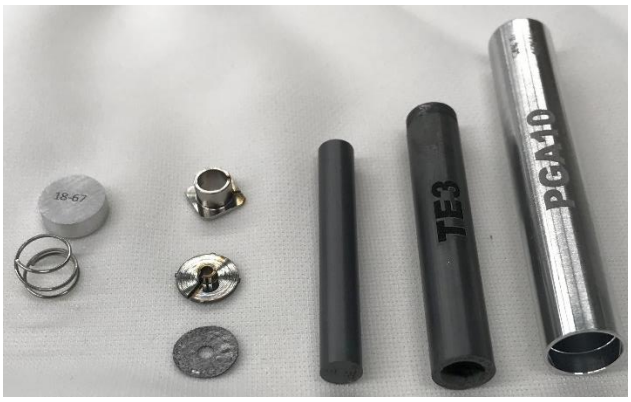
PGA05

PGA06

PGA07

PGA08

PGA09



PGA10

PGA11

Figure 3. Parts layout for capsules PGA01 through PGA11 (continued).

(a) (b)

Figure 4. Top-down view of (a) the capsule housing and the thermometry inside the tube specimen, and (b) the internal assembly.

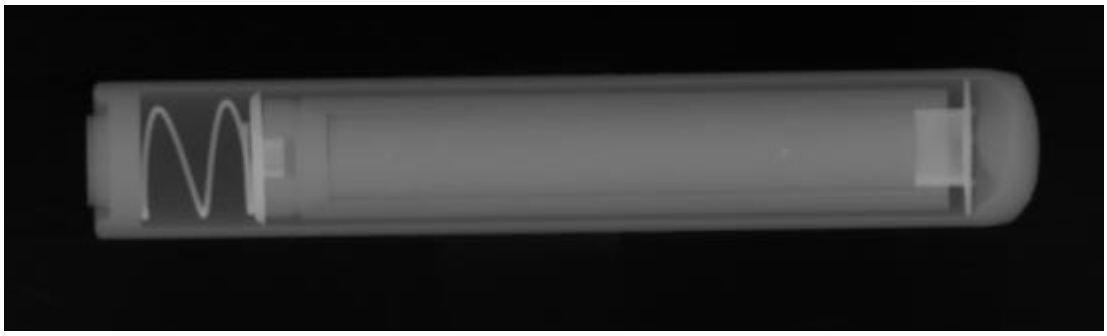


Figure 5. Radiograph of capsule PGA11.

All capsule components were dimensionally inspected and cleaned according to HFIR-approved procedures, drawings, and sketches. After assembly of the internal components, all rabbit housing end caps were welded to the housings using an electron beam weld. The capsules were then placed inside sealed chambers that were evacuated and backfilled three times to ensure a pure environment with the gas mixture specified in Table 1. The chambers were placed inside a glove box, which was also evacuated and backfilled with the same gas mixture. Each rabbit had a small hole in the bottom of the housing that was sealed using a gas tungsten arc welding procedure. All welds passed visual examination. Each capsule was then sent for nondestructive examination, which included a helium leak test, hydrostatic compression at a pressure of 1,035 psi, mass comparisons before and after hydrostatic compression to ensure no water penetrated the capsule housing, and a final post-compression helium leak test. All rabbits passed helium leak testing and hydrostatic compression.

The capsules were delivered to HFIR, along with their fabrication package, which records requirements for design analyses, material certification, assembly procedure, welding, and testing. The signed capsule fabrication request forms are provided in APPENDIX A.

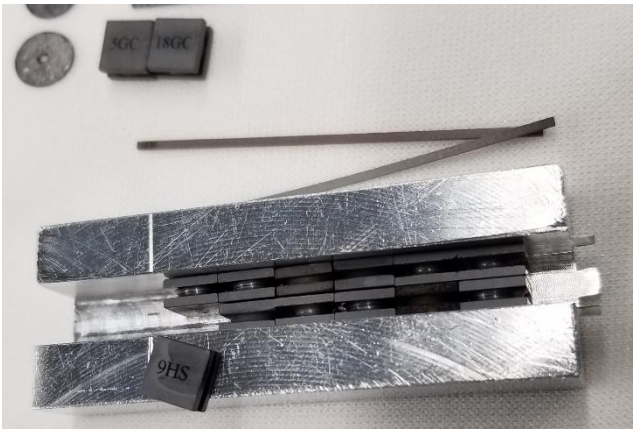
3.2 TORSION SPECIMENS CAPSULES ASSEMBLY

Two capsules containing torsion specimens, TGA01 and TGA02, were assembled. Figure 6 shows the complete part layouts for these two capsules. Each capsule contains sixteen torsion specimens. Figure 7 shows the assembly process, in which all the torsion specimens were lined up before being inserted in their holder and housing. Housings were chosen so that the as-built holder-to-housing gas gap matched the desired gaps within 1 µm (131 µm gap for capsule TGA01 and 83 µm for capsule TGA02).

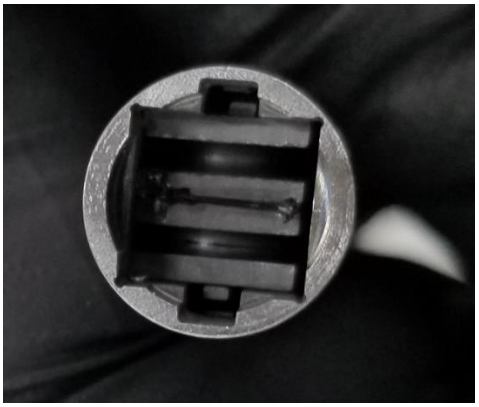
(a)

(b)

Figure 6. Part layout for (a) capsule TGA01 and (b) capsule TGA02.



(a)



(b)

Figure 7. Torsion specimens (a) being setup for insertion in their holder and (b) assembled in the holder and housing.

Like the end plug specimen capsules, all the components of the torsion specimen capsules were dimensionally inspected and cleaned according to HFIR-approved procedures, drawings, and sketches. The signed capsule fabrication request forms are provided in APPENDIX A.

4. SUMMARY AND CONCLUSIONS

This report summarizes the test matrix and assembly of eleven tube specimen rabbit capsules that were successfully delivered to HFIR for insertion during cycle 485 (December 2019). Two torsion specimens rabbit capsules were also assembled. The capsules contain one of two types of specimen geometry (tube or torsion), where each specimen features one of three different joint variations (TEP, oxide, or hybrid). Post-irradiation examination will analyze the joints' mechanical and thermal properties, permeability, and microstructure. Ultimately, the results of this project will aid in understanding the effects of irradiation on SiC joint performance.

5. WORKS CITED

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[6] K. G. Field et al., "Evaluation of the Continuous Dilatometer Method of Silicon Carbide Thermometry for Passive Irradiation Temperature Determination," *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms,* vol. 445, pp. 46–56, 2019.

APPENDIX A. FABRICATION REQUEST SHEETS

APPENDIX A. FABRICATION REQUEST SHEETS

Capsule Number: PGA01

Irradiation Conditions

Irradiation Location	TRRH 7	
Design Temperature	350	
First Cycle Goal	485	
Irradiation Time	2.0	cyc.
Fill Gas	Helium	

Approvals

	Request	Build
Performed by:	11/13/19	11/13/19
Checked by:	Chris Petti 11-12-19	11-12-19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	Al 6061	1		20713	20713	17-107	4.3016
End Cap	X3E020977A634	C	2	Al 4047	1		20823	20850	18-58	0.6155
Compression Spring	S17-42-SIC_ENDPLUG	0	2	304 SS	1		20659	21006	01	0.1088
Insulator Disk	S17-42-SIC_ENDPLUG	0	3	Grafoil	1		19812	19812	1 total	0.0088
End Plug Specimen	S17-43-SIC_ENDPLUG	1	1	SiC	1	GC1	20992	20992	CA TUBE 1	4.4851
Bottom Centering Thimble	S17-43-SIC_ENDPLUG	1	2	Ti-6Al4V	1	Ø5.48 ± 0.03	20950	20950	1 total	0.2196
Thermometry	S17-43-SIC_ENDPLUG	1	3	SiC	1		19759	20948	CA 1	3.0635
Top Centering Thimble	S17-43-SIC_ENDPLUG	1	4	Ti-6Al4V	1		20950	20950	18-01	0.2257
									total mass	13.0286
									specimen mass	4.4851

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S17-42-SIC_ENDPLUG	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			Helium

Capsule Number: PGA02

Irradiation Conditions

Irradiation Location	TRRH 7	
Design Temperature	350	
First Cycle Goal	485	
Irradiation Time	2.0	cyc.
Fill Gas	Helium	

Approvals

	Request	Build
Performed by:	11/13/19	11-12-19
Checked by:	Chris Fetter 11-12-19	11/13/19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	Al 6061	1		20713	20713	17-135	4.3083
End Cap	X3E020977A634	C	2	Al 4047	1		20823	20850	18-59	0.6153
Compression Spring	S17-42-SIC_ENDPLUG	0	2	304 SS	1		20659	21006	02	0.1066
Insulator Disk	S17-42-SIC_ENDPLUG	0	3	Grafoil	1		19812	19812	1 total	0.0087
End Plug Specimen	S17-43-SIC_ENDPLUG	1	1	SiC	1	GC2	20992	20992	CA TUBE 2	4.2169
Bottom Centering Thimble	S17-43-SIC_ENDPLUG	1	2	Ti-6Al4V	1	Ø5.58 ± 0.03	20950	20950	1 total	0.2144
Thermometry	S17-43-SIC_ENDPLUG	1	3	SiC	1		19759	20948	CA 2	3.0692
Top Centering Thimble	S17-43-SIC_ENDPLUG	1	4	Ti-6Al4V	1		20950	20950	18-02	0.2253
									total mass	12.7647
									specimen mass	4.2169

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S17-42-SIC_ENDPLUG	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			Helium

Capsule Number: PGA03

Irradiation Conditions

Irradiation Location	TRRH 7	
Design Temperature	750	
First Cycle Goal	485	
Irradiation Time	2.0	cyc.
Fill Gas	46% He, Ar bal.	

Approvals

	Request	Build
Performed by:	11/13/19	11/13/19
Checked by:	Chris Petrie 11-12-19	11-12-19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	Al 6061	1		20838	20839	18-20	4.3098
End Cap	X3E020977A634	C	2	Al 4047	1		20823	20850	18-60	0.6120
Compression Spring	S17-42-SIC_ENDPLUG	0	2	304 SS	1		20659	21006	03	0.1011
Insulator Disk	S17-42-SIC_ENDPLUG	0	3	Grafoil	1		19812	19812	1 total	0.0087
End Plug Specimen	S17-43-SIC_ENDPLUG	1	1	SiC	1	GC3	20992	20992	CA TUBE 3	4.1171
Bottom Centering Thimble	S17-43-SIC_ENDPLUG	1	2	Ti-6Al4V	1	Ø5.58 ± 0.03	20950	20950	1 total	0.2187
Thermometry	S17-43-SIC_ENDPLUG	1	3	SiC	1		19759	20948	CA 3	3.3952
Top Centering Thimble	S17-43-SIC_ENDPLUG	1	4	Ti-6Al4V	1		20950	20950	18-03	0.2242
									total mass	12.9868
									specimen mass	4.1171

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S17-42-SIC_ENDPLUG	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			46% He, Ar bal.

Capsule Number: PGA04

Irradiation Conditions

Irradiation Location	TRRH 7	
Design Temperature	750	
First Cycle Goal	485	
Irradiation Time	2.0	cyc.
Fill Gas	46% He, Ar bal.	

Approvals

	Request	Build
Performed by:	11/13/19	11/13/19
Checked by:	Chris Petrie 11-12-19	11.12.19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	Al 6061	1		20838	20839	18-21	4.2986
End Cap	X3E020977A634	C	2	Al 4047	1		20823	20850	18-61	0.6149
Compression Spring	S17-42-SIC_ENDPLUG	0	2	304 SS	1		20659	21006	04	0.0994
Insulator Disk	S17-42-SIC_ENDPLUG	0	3	Grafoil	1		19812	19812	1 total	0.0084
End Plug Specimen	S17-43-SIC_ENDPLUG	1	1	SiC	1	GC7	20992	20992	CA TUBE 7	4.3983
Bottom Centering Thimble	S17-43-SIC_ENDPLUG	1	2	Ti-6Al4V	1	Ø5.48 ± 0.03	20950	20950	1 total	0.2066
Thermometry	S17-43-SIC_ENDPLUG	1	3	SiC	1		19759	20948	CA 7	3.0774
Top Centering Thimble	S17-43-SIC_ENDPLUG	1	4	Ti-6Al4V	1		20950	20950	18-04	0.2249
									total mass	12.9285
									specimen mass	4.3983

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S17-42-SIC_ENDPLUG	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			46% He, Ar bal.

Capsule Number: PGA05

Irradiation Conditions

Irradiation Location	TRRH 7	
Design Temperature	350	
First Cycle Goal	485	
Irradiation Time	2.0	cyc.
Fill Gas	Helium	

Approvals

	Request	Build
Performed by:	11/13/15	11/13/19
Checked by:	Chris Petrie 11-12-19	11-12-19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	Al 6061	1		20838	20839	18-23	4.2962
End Cap	X3E020977A634	C	2	Al 4047	1		20823	20850	18-62	0.6157
Compression Spring	S17-42-SIC_ENDPLUG	0	2	304 SS	1		20659	21006	05	0.1023
Insulator Disk	S17-42-SIC_ENDPLUG	0	3	Grafoil	1		19812	19812	1 total	0.0078
End Plug Specimen	S17-43-SIC_ENDPLUG	1	1	SiC	1	HS3	20992	20992	HSiC TUBE 3	4.0204
Bottom Centering Thimble	S17-43-SIC_ENDPLUG	1	2	Ti-6Al4V	1	Ø5.76 ± 0.03	20950	20950	1 total	0.2138
Thermometry	S17-43-SIC_ENDPLUG	1	3	SiC	1		19759	20948	HS3	3.5322
Top Centering Thimble	S17-43-SIC_ENDPLUG	1	4	Ti-6Al4V	1		20950	20950	18-05	0.2237
									total mass	13.0121
									specimen mass	4.0204

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S17-42-SIC_ENDPLUG	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			Helium

Capsule Number: PGA06

Irradiation Conditions

Irradiation Location	TRRH 7	
Design Temperature	350	
First Cycle Goal	485	
Irradiation Time	2.0	cyc.
Fill Gas	Helium	

Approvals

	Request	Build
Performed by:	11/13/19	11/13/19
Checked by:	Chris Petrie 11-12-19	11.12.19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	Al 6061	1		20838	20839	18-30	4.2959
End Cap	X3E020977A634	C	2	Al 4047	1		20823	20850	18-63	0.6145
Compression Spring	S17-42-SIC_ENDPLUG	0	2	304 SS	1		20659	21006	06	0.1067
Insulator Disk	S17-42-SIC_ENDPLUG	0	3	Grafoil	1		19812	19812	1 total	0.0078
End Plug Specimen	S17-43-SIC_ENDPLUG	1	1	SiC	1	HS7	20992	20992	HSiC TUBE 7	3.9848
Bottom Centering Thimble	S17-43-SIC_ENDPLUG	1	2	Ti-6Al4V	1	Ø5.76 ± 0.03	20950	20950	1 total	0.2151
Thermometry	S17-43-SIC_ENDPLUG	1	3	SiC	1		19759	20948	HS7	3.5317
Top Centering Thimble	S17-43-SIC_ENDPLUG	1	4	Ti-6Al4V	1		20950	20950	18-06	0.2273
									total mass	12.9838
									specimen mass	3.9848

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S17-42-SIC_ENDPLUG	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			Helium

Capsule Number: PGA07

Irradiation Conditions

Irradiation Location	TRRH 7	
Design Temperature	750	
First Cycle Goal	485	
Irradiation Time	2.0	cyc.
Fill Gas	46% He, Ar bal.	

Approvals

	Request	Build
Performed by:	11/13/19	11/13/19
Checked by:	Chris Petrie 11-12-19	11-12-19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	Al 6061	1		20838	20839	18-38	4.2762
End Cap	X3E020977A634	C	2	Al 4047	1		20823	20850	18-64	0.6147
Compression Spring	S17-42-SIC_ENDPLUG	0	2	304 SS	1		20659	21006	07	0.1018
Insulator Disk	S17-42-SIC_ENDPLUG	0	3	Grafoil	1		19812	19812	1 total	0.0077
End Plug Specimen	S17-43-SIC_ENDPLUG	1	1	SiC	1	HS8	20992	20992	HSiC TUBE 8	4.2046
Bottom Centering Thimble	S17-43-SIC_ENDPLUG	1	2	Ti-6Al4V	1	Ø5.64 ± 0.03	20950	20950	1 total	0.2151
Thermometry	S17-43-SIC_ENDPLUG	1	3	SiC	1		19759	20948	HS8	3.3797
Top Centering Thimble	S17-43-SIC_ENDPLUG	1	4	Ti-6Al4V	1		20950	20950	18-07	0.2245
									total mass	13.0243
									specimen mass	4.2046

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S17-42-SIC_ENDPLUG	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			46% He, Ar bal.

Capsule Number: PGA08

Irradiation Conditions

Irradiation Location	TRRH 7	
Design Temperature	750	
First Cycle Goal	485	
Irradiation Time	2.0	cyc.
Fill Gas	46% He, Ar bal.	

Approvals

	Request	Build
Performed by:	11/13/19	11/13/19
Checked by:	Chris Petrie 11-12-19	11-12-19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	Al 6061	1		20838	20839	18-71	4.3454
End Cap	X3E020977A634	C	2	Al 4047	1		20823	20850	18-65	0.6158
Compression Spring	S17-42-SIC_ENDPLUG	0	2	304 SS	1		20659	21006	08	0.0967
Insulator Disk	S17-42-SIC_ENDPLUG	0	3	Grafoil	1		19812	19812	1 total	0.0087
End Plug Specimen	S17-43-SIC_ENDPLUG	1	1	SiC	1	TE2	20992	20992	TEP TUBE 2	4.2049
Bottom Centering Thimble	S17-43-SIC_ENDPLUG	1	2	Ti-6Al4V	1	Ø5.58 ± 0.03	20950	20950	1 total	0.2156
Thermometry	S17-43-SIC_ENDPLUG	1	3	SiC	1		19759	20948	TEP2	3.2345
Top Centering Thimble	S17-43-SIC_ENDPLUG	1	4	Ti-6Al4V	1		20950	20950	18-08	0.2259
									total mass	12.9475
									specimen mass	4.2049

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S17-42-SIC_ENDPLUG	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			46% He, Ar bal.

Capsule Number: PGA09

Irradiation Conditions

Irradiation Location	TRRH 7	
Design Temperature	750	
First Cycle Goal	485	
Irradiation Time	2.0	cyc.
Fill Gas	46% He, Ar bal.	

Approvals

	Request	Build
Performed by:	11/13/19	11-12-19
Checked by:	Chris Rettig 11-12-19	11/18/19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	Al 6061	1		20838	20839	18-76	4.3127
End Cap	X3E020977A634	C	2	Al 4047	1		20823	20850	18-66	0.6145
Compression Spring	S17-42-SIC_ENDPLUG	0	2	304 SS	1		20659	21006	09	0.1040
Insulator Disk	S17-42-SIC_ENDPLUG	0	3	Grafoil	1		19812	19812	1 total	0.0086
End Plug Specimen	S17-43-SIC_ENDPLUG	1	1	SiC	1	HS9	20992	20992	HSiC TUBE 9	3.8837
Bottom Centering Thimble	S17-43-SIC_ENDPLUG	1	2	Ti-6Al4V	1	Ø5.64 ± 0.03	20950	20950	1 total	0.2239
Thermometry	S17-43-SIC_ENDPLUG	1	3	SiC	1		19759	20948	HS9	3.3789
Top Centering Thimble	S17-43-SIC_ENDPLUG	1	4	Ti-6Al4V	1		20950	20950	18-09	0.2249
									total mass	12.7512
									specimen mass	3.8837

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S17-42-SIC_ENDPLUG	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			46% He, Ar bal.

Capsule Number: PGA10

Irradiation Conditions

Irradiation Location	TRRH 7	
Design Temperature	750	
First Cycle Goal	485	
Irradiation Time	2.0	cyc.
Fill Gas	46% He, Ar bal.	

Approvals

	Request	Build
Performed by:	11/12/19	11-12-19
Checked by:	Chris Petrie 11-12-19	11/13/19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	Al 6061	1		20838	20839	18-88	4.3255
End Cap	X3E020977A634	C	2	Al 4047	1		20823	20850	18-67	0.6159
Compression Spring	S17-42-SIC_ENDPLUG	0	2	304 SS	1		20659	21006	10	0.1071
Insulator Disk	S17-42-SIC_ENDPLUG	0	3	Grafoil	1		19812	19812	1 total	0.0077
End Plug Specimen	S17-43-SIC_ENDPLUG	1	1	SiC	1	TE3	20992	20992	TEP TUBE 3	4.1404
Bottom Centering Thimble	S17-43-SIC_ENDPLUG	1	2	Ti-6Al4V	1	Ø5.64 ± 0.03	20950	20950	1 total	0.2181
Thermometry	S17-43-SIC_ENDPLUG	1	3	SiC	1		19759	20948	TEP3	3.4402
Top Centering Thimble	S17-43-SIC_ENDPLUG	1	4	Ti-6Al4V	1		20950	20950	18-10	0.2255
									total mass	13.0804
									specimen mass	4.1404

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S17-42-SIC_ENDPLUG	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			46% He, Ar bal.

Capsule Number: PGA11

Irradiation Conditions

Irradiation Location	TRRH 7	
Design Temperature	350	
First Cycle Goal	485	
Irradiation Time	2.0	cyc.
Fill Gas	Helium	

Approvals

	Request	Build
Performed by:	11/13/19	11-12-19
Checked by:	Chris Ritzo 11-12-19	11/13/19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	Al 6061	1		20838	20839	18-99	4.3158
End Cap	X3E020977A634	C	2	Al 4047	1		20823	20850	18-68	0.6156
Compression Spring	S17-42-SIC_ENDPLUG	0	2	304 SS	1		20659	21006	11	0.0940
Insulator Disk	S17-42-SIC_ENDPLUG	0	3	Grafoil	1		19812	19812	1 total	0.0086
End Plug Specimen	S17-43-SIC_ENDPLUG	1	1	SiC	1	TE9	20992	20992	TEP TUBE 9	4.2595
Bottom Centering Thimble	S17-43-SIC_ENDPLUG	1	2	Ti-6Al4V	1	Ø5.48 ± 0.03	20950	20950	1 total	0.2113
Thermometry	S17-43-SIC_ENDPLUG	1	3	SiC	1		19759	20948	TEP9	3.2062
Top Centering Thimble	S17-43-SIC_ENDPLUG	1	4	Ti-6Al4V	1		20950	20950	18-11	0.2229
									total mass	12.9339
									specimen mass	4.2595

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S17-42-SIC_ENDPLUG	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			Helium

Capsule Fabrication Request Sheet

Capsule Number: TGA01

Irradiation Conditions

Irradiation Location	TRRH 7
First Cycle Goal	485
Irradiation Time	2.0 cycles
Irradiation Temperature	300°C
Housing Fill Gas	Helium

Approvals

	Request	Build
Performed by:	11/6/19	11/6/19
Checked by:	11-6-19	10/30/19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	Al 6061	1		20930	20930	19-15	4.2627
End Cap	X3E020977A634	C	2	Al 4047	1		20823	20850	18-77	0.6160
Center Spacer	S10-05-TTN01	C	2	Grafoil	1	6.0 x 48.0 x 0.15 thk	19812	19812	1 Total	0.0374
Retainer Spring	S10-05-TTN01	C	3	SiC	2		19759	19759	2 Total	0.0566
Support Disk	S10-05-TTN01	C	4	Molybdenum	2	Ø7.5 x 0.05-0.13 thk	19593	19593	2 Total	0.06270
Outer Insulator Disk	S10-05-TTN01	C	5	Grafoil	2	Ø9.2 x 0.05-0.13 thk	19812	19812	2 Total	0.0172
Insulator Disk	S10-05-TTN01	C	6	Grafoil	6	Ø7.5 x 0.05-0.13 thk	19812	19812	6 Total	0.0343
Specimen Holder Type A	JLM04012008-1	B	1	V-4Cr4Ti	1	9.260 mm OD	19599	21008	V1	7.5212
Joint Specimen	S10-05-TTN01	C	8	SiC	16		20989	20989	1TE	0.2614
									7TE	0.2620
									1GC	0.2972
									15GC	0.2966
									1HS	0.2995
									11HS	0.3095
									3TE	0.2618
									9TE	0.2619
									5GC	0.2985
									18GC	0.3017
									9HS	0.3136
									13HS	0.2995
									5TE	0.2615
									10GC	0.3007
									5HS	0.2903
									11GC	0.2988
Quartz Wool	S10-05-TTN01	C	9	Quartz	AR		20679	20679	AR	0.0120
Centering Thimble	X3E020977A540	1	1	Ti-6Al4V	2		20536	20553	2 Total	0.2768
Small Thermometry	X3E020977A540	1	3	SiC	2	317,319	19502	19709	2 Total	0.1330
									Total Mass	17.6644
									Specimen Mass	4.8041
									Internal Mass	12.7657

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S10-05-TTN01	C	
Welding & Cleaning	X3E020977A633	2	
Fill Gas	Helium		

Capsule Fabrication Request Sheet

Date 11/6/2019

Capsule Number: TGA02

Irradiation Conditions

Irradiation Location	TRRH 7
First Cycle Goal	485
Irradiation Time	2.0 cycles
Irradiation Temperature	800°C
Housing Fill Gas	Argon

Approvals

	Request	Build
Performed by:	11/06/19	11/6/19
Checked by:	11-6-19	11-06-19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	Al 6061	1		20930	20930	19-24	4.2992
End Cap	X3E020977A634	C	2	Al 4047	1		20823	20850	18-78	0.6142
Center Spacer	S10-05-TTN01	C	2	Grafoil	1	6.0 x 48.0 x 0.15 thk	19812	19812	1 Total	0.0373
Retainer Spring	S10-05-TTN01	C	3	SiC	2		19759	19759	2 Total	0.0554
Support Disk	S10-05-TTN01	C	4	Molybdenum	2	Ø7.5 x 0.05-0.13 thk	19593	19593	2 Total	0.06200
Outer Insulator Disk	S10-05-TTN01	C	5	Grafoil	2	Ø9.2 x 0.05-0.13 thk	19812	19812	2 Total	0.0178
Insulator Disk	S10-05-TTN01	C	6	Grafoil	6	Ø7.5 x 0.05-0.13 thk	19812	19812	6 Total	0.0344
Specimen Holder Type A	JLM04012008-1	B	1	Nb-1Zr	1	9.356 mm OD	20339	21008	N2	11.2749
Joint Specimen	S10-05-TTN01	C	8	SiC	16		20989	20989	2TE	0.2619
									8TE	0.2618
									16GC	0.2990
									17GC	0.2985
									2HS	0.2883
									19HS	0.3055
									17HS	0.3079
									14HS	0.3033
									4TE	0.2617
									11TE	0.2621
									4GC	0.2978
									7GC	0.2977
									8HS	0.3110
									6TE	0.2633
									10TE	0.2628
									20GC	0.2995
Quartz Wool	S10-05-TTN01	C	9	Quartz	AR		20679	20679	AR	0.0201
Centering Thimble	X3E020977A540	1	1	Ti-6Al4V	2		20536	20553	2 Total	0.2796
Small Thermometry	X3E020977A540	1	3	SiC	2	324,374	19502	19709	2 Total	0.1324
									Total Mass	21.4094
									Specimen Mass	4.7699
									Internal Mass	16.4960

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S10-05-TTN01	C	
Welding & Cleaning	X3E020977A633	2	
Fill Gas	Argon		