ORNL/SPR-2019/1306

Design and Assembly of Rabbit Capsules for Irradiation of Prototype Metal and Nanocomposite Specimens in the High Flux Isotope Reactor

Sean Piela
Richard H. Howard
Annabelle G. Le Coq
Kory D. Linton
Ju Li

**Approved for public release.
Distribution is unlimited.**

September 27, 2019

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

ORNL/SPR-2019/1306

Reactor and Nuclear Systems Division

Design and Assembly of Rabbit Capsules for Irradiation of Prototype Metal and Nanocomposite Specimens in the High Flux Isotope Reactor

Sean Piela
Richard Howard
Annabelle G. Le Coq
Kory D. Linton
Ju Li

Date Published: September 27, 2019

NSUF Work Package #: UF-19OR021113
Work Package Manager: Kory Linton
Milestone #: M3UF-19OR0211132

Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, TN 37831-6283
managed by
UT-BATTELLE, LLC
for the
US DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

This research was sponsored by the Nuclear Science User Facilities Program of the US Department of Energy, Office of Nuclear Energy. Neutron irradiation in the High Flux Isotope Reactor is made possible by the Office of Basic Energy Sciences, DOE. The report was authored by UT-Battelle under contract number DE-AC05-00OR22725 with DOE. The different materials were provided by the Massachusetts Institute of Technology with the help of Kangpyo So, Rui Gao, So Yeon Kim, Mohammad Hasan Shahin, Myles Stapelberg, Samuel McAlpine, and by Oak Ridge National Laboratory staff members Niyanth Niyanth and Caleb Massey.

SUMMARY

The Massachusetts Institute of Technology has developed a manufacturing process for nanodispersion-strengthened materials that could be used as fuel cladding or reactor core materials. This report describes the design concept of irradiation capsules intended to accommodate specimens from such materials. The capsules will be irradiated in the flux trap of Oak Ridge National Laboratory's High Flux Isotope Reactor at three different fluence levels. The goal of this neutron irradiation is to investigate the effects of irradiation on those materials at the nanoscale. In addition, the report describes the irradiation test matrix and the successful assembly of the irradiation capsules.

ACRONYMS

CNT	carbon nanotube
GENTEN	general tensile
HFIR	High Flux Isotope Reactor
HT	hydraulic tube
MIT	Massachusetts Institute of Technology
O/C	oxides/carbides
OD	outside diameter
ORNL	Oak Ridge National Laboratory
PTP	peripheral target position
RB	removable beryllium
SiC	silicon carbide
TRRH	target rod rabbit holder
VXF	vertical experiment facility

1. INTRODUCTION

The Massachusetts Institute of Technology (MIT) is currently studying different materials with improved neutron irradiation resistance provided by nanodispersion that could be used as fuel cladding or reactor core material. The nanodispersion manufacturing technique uses 0, 1, or 2 dimensions (i.e., 0D, 1D, or 2D) nanodispersions, which correspond to particles, nanotubes, or sheets, respectively. The goal of this project is to perform neutron irradiation testing of several nanodispersion-strengthened materials to provide data on the mechanism of defects at the nanoscale.

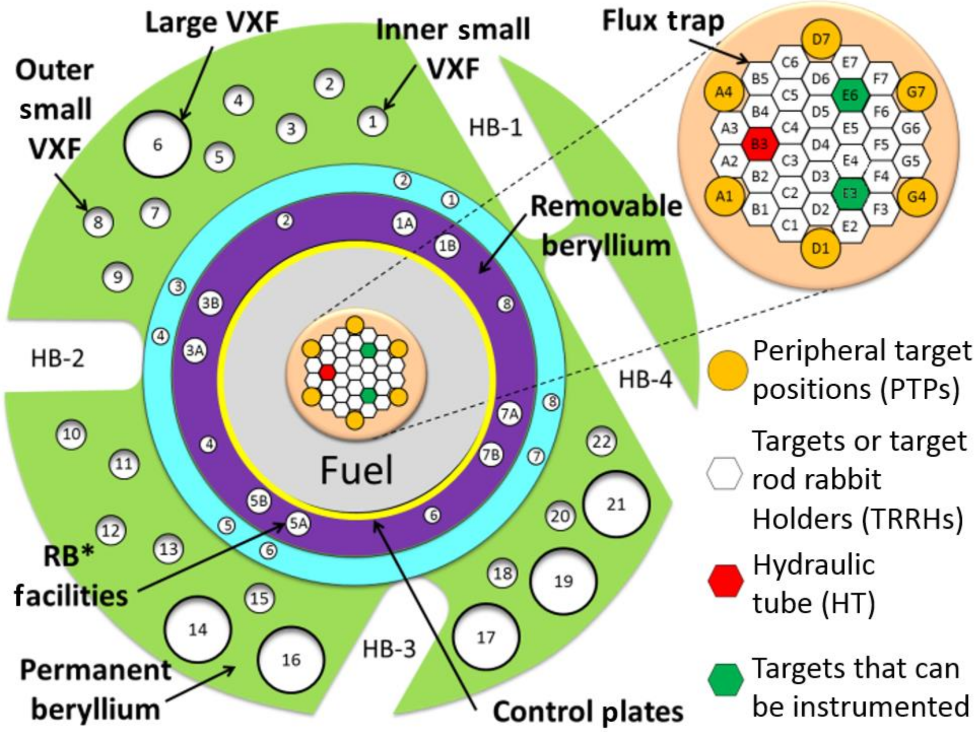
The specimens from 13 MIT nanodispersion-strengthened materials will be inserted in rabbit capsules and irradiated at 3 different fluence levels in the Oak Ridge National Laboratory (ORNL) High Flux Isotope Reactor (HFIR). Each material is intended to be irradiated at each irradiation condition; all irradiations' design target temperature is of 300 ± 50°C with doses of approximately 0.7, 1.4, and 2.1 dpa (approximately one-half, one, and two cycles in HFIR, respectively). A total of six capsules will be irradiated (two capsules per irradiation condition). This report presents the design concept for the experiment, the test matrix, and the successful assembly of these capsules.

2. EXPERIMENT DESIGN AND TEST MATRIX

HFIR is a beryllium-reflected, pressurized, light-water-cooled and light-water-moderated flux trap-type reactor located at ORNL. HFIR's core consists of aluminum-clad involute-fuel plates that currently use highly enriched ^{235}U fuel to maintain a steady state power level of 85 MWth [1]. Most irradiation experiments are conducted in the flux trap—typically in small, uninstrumented rabbit capsules. As many as eight rabbits can be stacked axially inside a single peripheral target position (PTP) holder, a target rod rabbit holder (TRRH), or the hydraulic tube (HT). The target rod and peripheral target holders have orifices that establish capsule heat transfer boundary conditions for rabbits with respect to the reactor primary coolant. Positions are numbered in increasing order from the bottom to the top of a PTP or TRRH, so positions TRRH-4 and PTP-5, for instance, would be closest to the reactor's midplane.

Neutron and gamma radiation from HFIR fuel cause heating of experiment materials. This heating is accurately determined using neutronics models of the HFIR core and is used as an input to finite element thermal analyses that estimate experiment component temperatures during irradiation. Experiments in the flux trap are usually uninstrumented; passive silicon carbide (SiC) temperature monitors (thermometry) are used to estimate the irradiation temperature during post irradiation examination [2]. Detailed neutronic and thermal analyses are used to engineer rabbits in which the predicted and measured integral-irradiation temperatures are as similar as possible. Experiment designs generally use a small insulating gas gap between the capsule's internal components and external housing (the exterior of which is in contact with the reactor's primary coolant). The size of the gap and the type of fill gas (helium, neon, or argon) inside the experiment are chosen so that the heat generated in the experimental components passes through the gas gap and produces a specified steady-state temperature in the interior of the rabbit. The temperature drop through this gas gap is a function of the heat flux through the gap, thermal conductivity of the fill gas, and size of the gas gap. Each of these parameters is carefully selected and modeled to achieve the design temperature in an experiment.

ANSYS finite element analysis software is used to predict temperature distributions inside the experiments. These analyses use material-dependent heat generation rates (heat per unit mass), which were calculated from previously determined neutronics analyses (such as in [3]). Computer-aided design models are imported into ANSYS and used to perform thermal analyses and optimize gas-gap dimensions. Convection boundary conditions are applied to the outer surface of the housing. The heat generation rates vary in each irradiation location and as a function of axial distance from the reactor core midplane. As shown in Figure 1, there are multiple irradiation facility designations in the HFIR flux trap.



* RB: removable beryllium
VXF: vertical experiment facility

Figure 1. Schematic showing transverse section view of HFIR core, reflector, and experimental positions (not to scale).

2.1 EXPERIMENT DESIGN CONCEPT

The flexible tensile capsule design, referred to as the general tensile (GENTEN), consists of three specimen holders stacked axially within the rabbit housing, as shown in Figure 2.

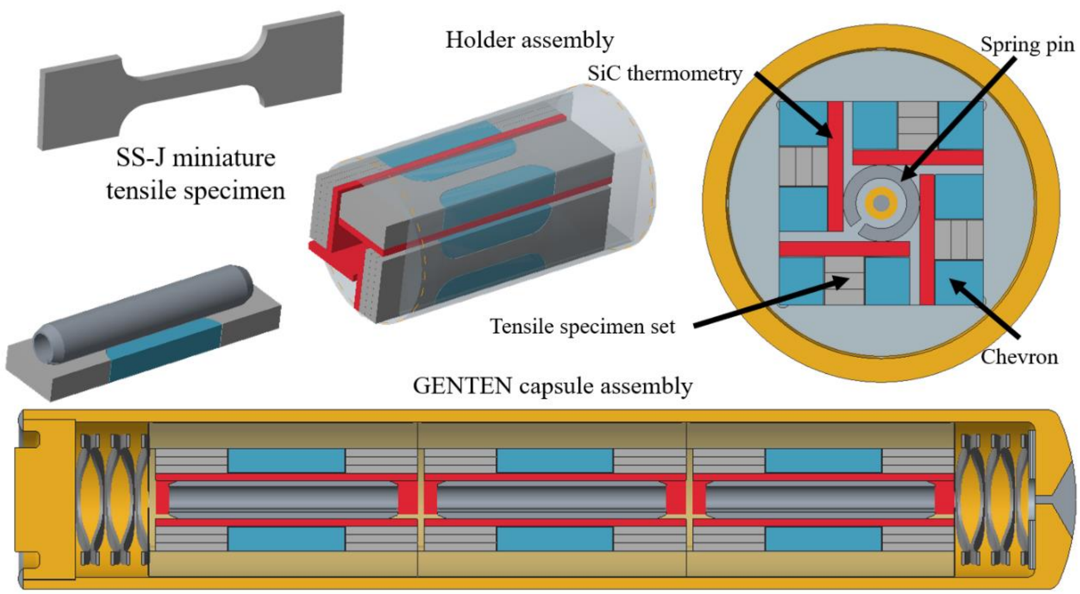


Figure 2. Section view of the GENTEN capsule design concept.

The outer containment for the irradiation experiment is the rabbit capsule housing, which is directly cooled on the outer surface by HFIR's primary coolant. The specimens are placed in holders with outer diameters (ODs) that are optimized to create gas gaps to control temperature performance. These holders can either be Al-6061 or molybdenum, depending on the required target temperature. Centering tabs with a slightly larger diameter are machined into the holders to keep the assemblies centered inside the housing and to maintain a constant gas gap between the holder and the housing. Stainless steel spring pins are used in the GENTEN design to hold the internal specimen in contact with the holder's inner walls. The chevrons are used as filler pieces that form a rectangular coupon shape with the tensile specimens to produce a uniform thermal load. Stainless steel wave springs are placed on the ends of the internal assembly between the housing and the holders to minimize axial heat loss.

2.2 CAPSULE THERMAL ANALYSIS

For the Nuclear Science User Facilities MIT tensile irradiation experiments, the specimen temperature is controlled by the axial location, fill gas, and size of the gap between the holder and housing. The GENTEN capsule concept is an implementation of the ESTEEL model described in ORNL-TM-2018-872 [4]. Table 2-1 lists the engineering drawings that define the GENTEN capsules used in this irradiation campaign.

Table 2-1. GENTEN capsule design drawings

Identifier	Part no.	Title or description
X3E020977A633, Rev. 2		Target Capsule Housing Assembly [5]
X3E020977A634, Rev. C		Target Capsule Housing/ End Cap Detail [6]
S16-18-FUSSAM01, Rev. 1	7	Chevron-SSJ-M4PCCVN-MPC-Thermometry
	3	SS-J2 specimen
CM08-L3-S17		Wave spring
91610A207		Spring pin
S18-39-GEN_TEN, Rev. 0	2	Holder and rabbit assembly

The various degrees of freedom for analysis inputs can create large numbers of single irradiation conditions. The GENTEN designs are intended to be easily deployed throughout the flux trap region, but explicitly analyzing all these cases is impractical. Therefore, a series of surface response calculations is performed on the capsule design. This approach effectively maps the target temperature design space for a given set of conditions (e.g., flux trap location-dependent heat generation rates, heat transfer boundary conditions, and holder ODs). The interface conditions between the capsules and HFIR coolant are listed in Table 2-2; these values are estimated in DAC-11-01-RAB03 [7].

Table 2-2. Heat transfer boundary conditions

Parameter	HFIR location	Value
Convective heat transfer coefficient [7]	TRRH	47.1 kW/m²·°C
	HT	31.6 kW/m²·°C
HFIR coolant temperature [7]	TRRH	52°C
	HT	53°C

Material properties for this calculation are taken from the design and analysis calculations listed in Table 2-3. Some specimen materials are uncommonly irradiated or completely new; these are modeled with the mechanical properties of similar materials (under the "Equivalence" column in the table).

Table 2-3. Material mechanical properties references

Material	Equivalence	Reference document
Aluminum 6061	n/a	DAC-10-03-PROP_AL6061 [8]
Molybdenum		DAC-10-11-PROP_MOLY [9]
Grafoil		DAC-11-16-PROP_GRAFOIL [10]
Austenitic steel Fe-18Cr-8Ni-2W-1Ti	304 stainless steel	DAC-10-16-PROP_SS304 [11]
410 stainless steel	F82H	DAC-10-10-PROP_F82H [12]
304 stainless steel	n/a	DAC-10-16-PROP_SS304 [11]
SiC		DAC-10-06-PROP_SIC(IRR) [13]
Copper		DAC-12-06-PROP_COPPER [14]
Nickel	n/a	DAC-13-15-PROP_NICKEL [15]
OFRAC	F82H	DAC-10-10-PROP_F82H [12]
Grade 91		
Helium	n/a	DAC-10-02-PROP_HELIUM [16]

The heat generation rates of the materials of construction (including specimens) are listed in Table 2-4, with reference documents specified. Some specimen materials are uncommonly irradiated or completely new; these are modeled with the heat generation rates of similar materials (under the "Equivalence" column in the table). Compound/blended materials composed overwhelmingly of one constituent are assumed to have the heat generation rate of that major constituent.

Table 2-4. Heat generations rates

Material	Equivalence	Mass-heating value (W/g)	Reference document
Aluminum 6061	n/a	32.5	DAC-10-18-RAB02 [3]
Molybdenum		43.3	
Grafoil		33.7	
Austenitic steel Fe-18Cr-8Ni-2W-1Ti	F82H	39.3	
410 stainless steel	F82H	39.3	
304 stainless steel			
SiC	n/a	32.9	
Copper		44.2	DAC-15-16-CNLN01-R0 [17]
Nickel	F82H	39.3	DAC-10-18-RAB02 [3]
OFRAC			
Grade 91			

In addition to the approximation of specimens' mechanical and heat generation properties, the ultimate selection of materials to be irradiated was uncertain during the thermal analysis stage of the campaign. That is, it was not specifically known which proposed experimental materials would be supplied, and the quantities of the supplied experimental materials were also uncertain during the thermal analysis stage of this campaign. Using the best available estimates of the spectrum of specimens, the steady-state thermal description of the rabbits was modeled (in ANSYS) as shown in Figure 3. The 1-D heat equation was used as a guide for the sorting of the specimens. Figure 3 shows that the predicted selection of tensile specimens to be irradiated in this campaign required two near-identical rabbits. In the material column, an entry of 30 represents 304 stainless steel and of 41 represents 410 stainless steel (the two-character abbreviations for the two steels is used simply such that all materials are described by two characters (visual stylization)). The quadrant column indicates in which GENTEN in-holder stack the specimens in the rows to the left are placed, for modeling. The letters L, T, R, and B stand for left, top, right, and bottom, respectively, corresponding to the stacks in Figure 4; though the stacks in a holder are symmetric, when viewing Figure 4, for example, the stacks have the appearance of L,T,R and B.

In Figure 3, the place-in-stack column uses letters to indicate if the specimen in the same row is the outermost, middle, or innermost (O, M, or I respectively) slab in the quadrants of stacks shown in Figure 4. The fourth (and innermost) slab in the quadrants shown in Figure 4 is SiC thermometry. Inside the rabbits, specimens are braced by F82H steel chevrons, except for in Holder 1 (see Figure 3), which uses some copper chevrons. The quadrants (that is, stacks of specimens) are pressed into each of the four corners of the square cutout in the holders using a steel spring pin. The holders have raised standoff features to center the holder assembly within the housing (as mentioned previously). Grafoil is used to insulate the holder subassemblies from the cool bottom of the aluminum housing. Figure 5 depicts a representative finite element meshing of a holder subassembly for the campaign rabbits.

Holder	#	Material #1	Material #2	Quadrant	Place in Stack	Chevron
Holder 1	1	Cu	Cu		O	
	2	Al	Al	L	M	Cu
	3	Cu	Cu		I	
	4	Al	Al	T	O	
	5	Cu	Cu		M	Cu
	6	Al	Al		I	
	7	Cu	Cu		O	
	8	Al	Al	R	M	Cu
	9	Cu	Cu		I	
	10	Al	Al		O	
	11	30	30		M	30
	12	30	30	B	I	
Holder 2	13	Ni	Ni		O	
	14	41	41	L	M	30
	15	Ni	Ni		I	
	16	41	30	T	O	
	17	Ni	Ni		M	30
	18	30	30		I	
	19	Ni	Ni		O	
	20	30	30	R	M	30
	21	Ni	Ni		I	
	22	41	41		O	
	23	41	41		M	30
	24	41	41	B	I	
Holder 3	25	Ni	Ni		O	
	26	Ni	Ni	L	M	30
	27	Ni	Ni		I	
	28	41	41	T	O	
	29	41	41		M	30
	30	41	41		I	
	31	Ni	Ni		O	
	32	41	41	R	M	30
	33	Ni	Ni		I	
	34	41	41		O	
	35	41	41		M	30
	36	41	41	B	I	

Figure 3. Predicted specimen selection, sorted into two rabbits.

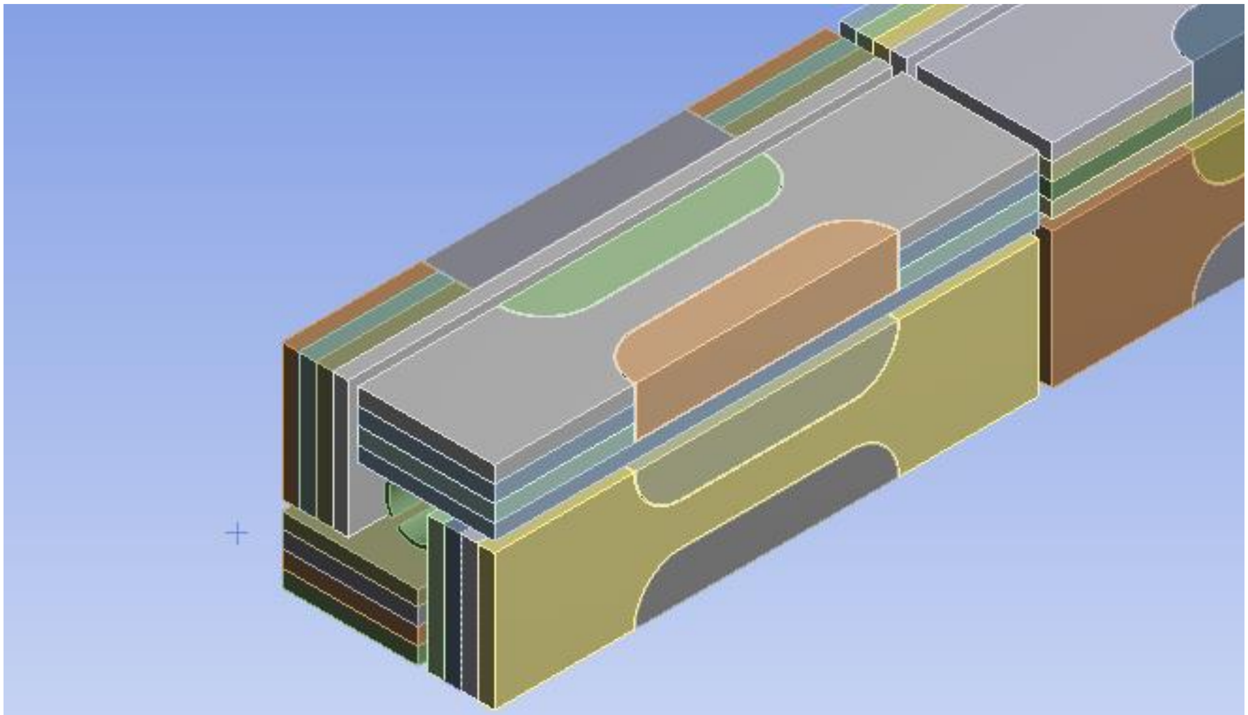


Figure 4. SS-J2 tensile specimen quadrant stacks in a GENTEN rabbit (isometric view).

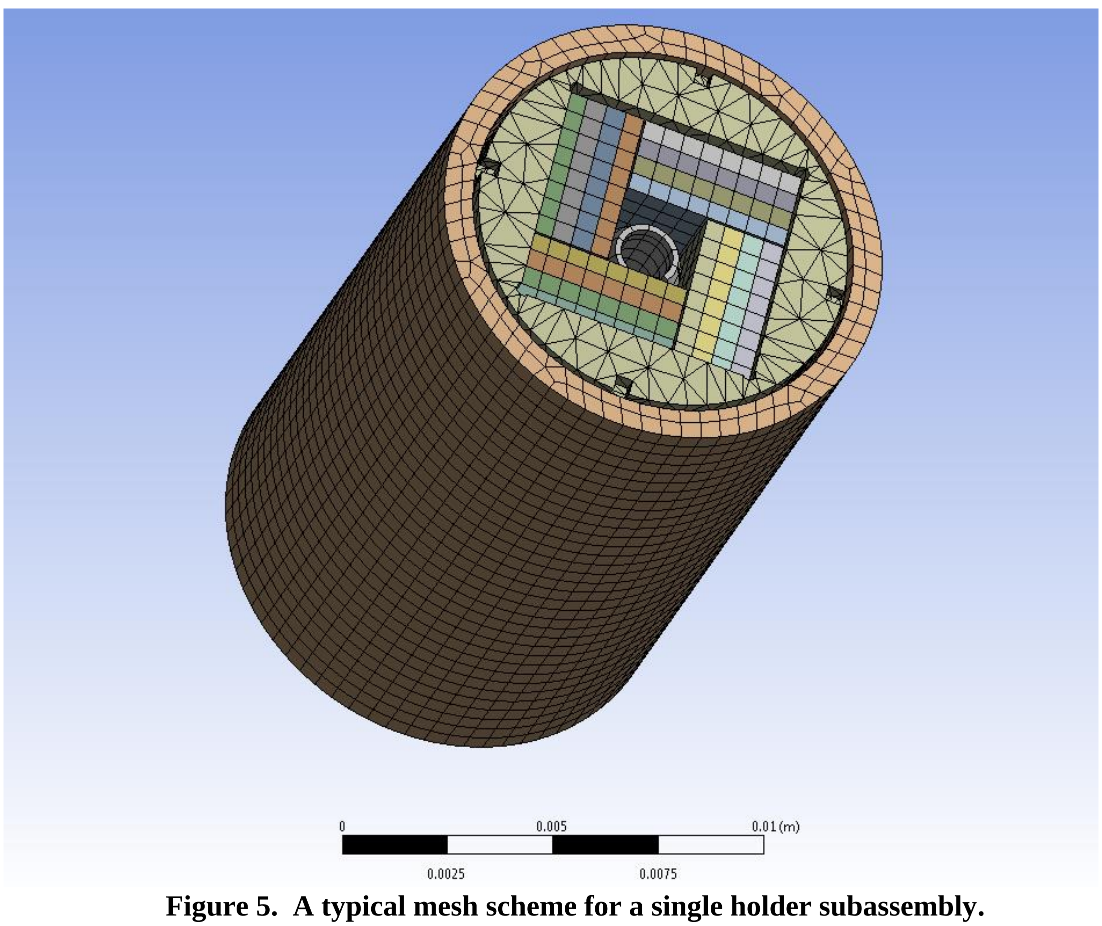


Figure 5. A typical mesh scheme for a single holder subassembly.

Using ANSYS (with customizations [18]), a parametric study of the rabbit 1 in Figure 3 was performed. Only rabbit 1 was studied because the only difference between the rabbits is that a single tensile specimen is 410 steel in one rabbit but 304 steel in the other. These materials are modeled to have the same heat generation rates. At the irradiation temperature target (300 °C), simulation of rabbit 1 shows that the 304 steel and 410 steel average specimen temperatures are comparable. Since estimates of holder-averaged specimens' temperatures would not be significantly different in a simulation of rabbit 2 (less than 5 °C), rabbit 2 was not simulated. The fill gas in all simulations was helium, while the OD of the three holders varied from 9.15 to 9.45 mm. The parametric study was run for both TRRH and HT, which were modeled as sets of discrete axial positions with differing heat generation rates. Several regions inside a rabbit were selected for steady-state temperature reporting, and those selected regions are depicted in Figure 6, Figure 7, Figure 8, and Figure 9..

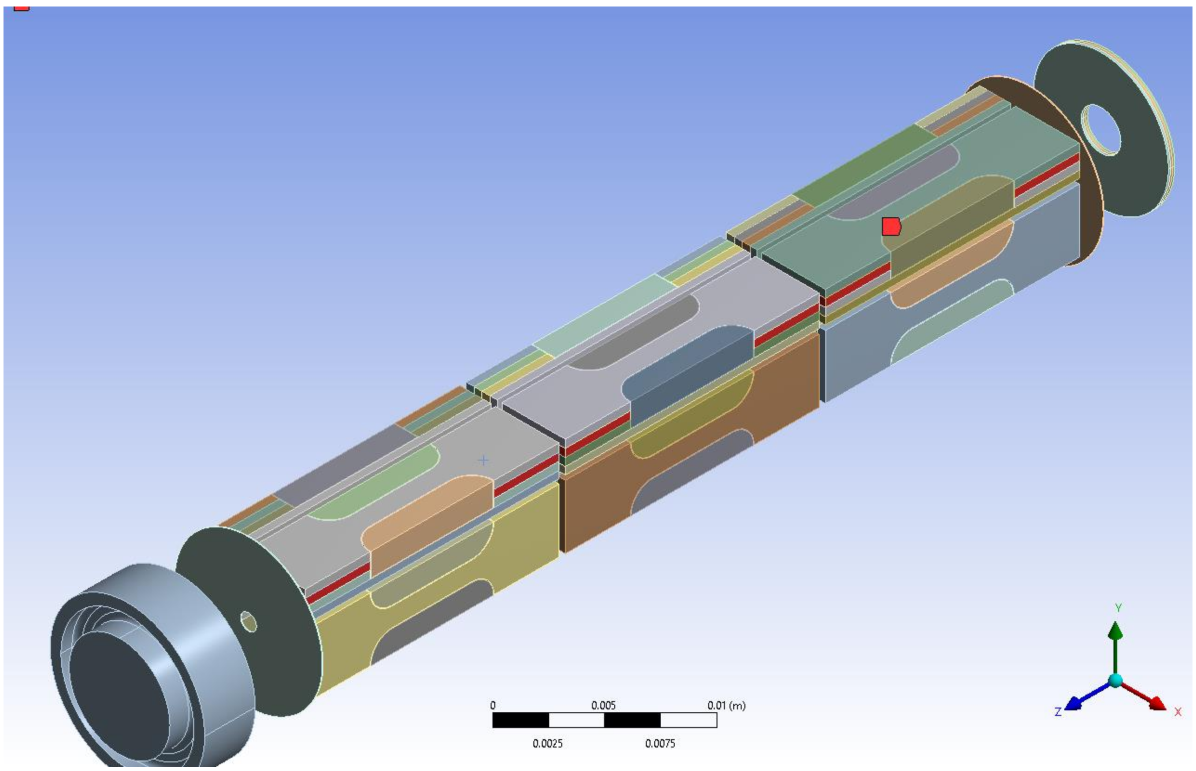


Figure 6. All top middle specimens grouping (T4)

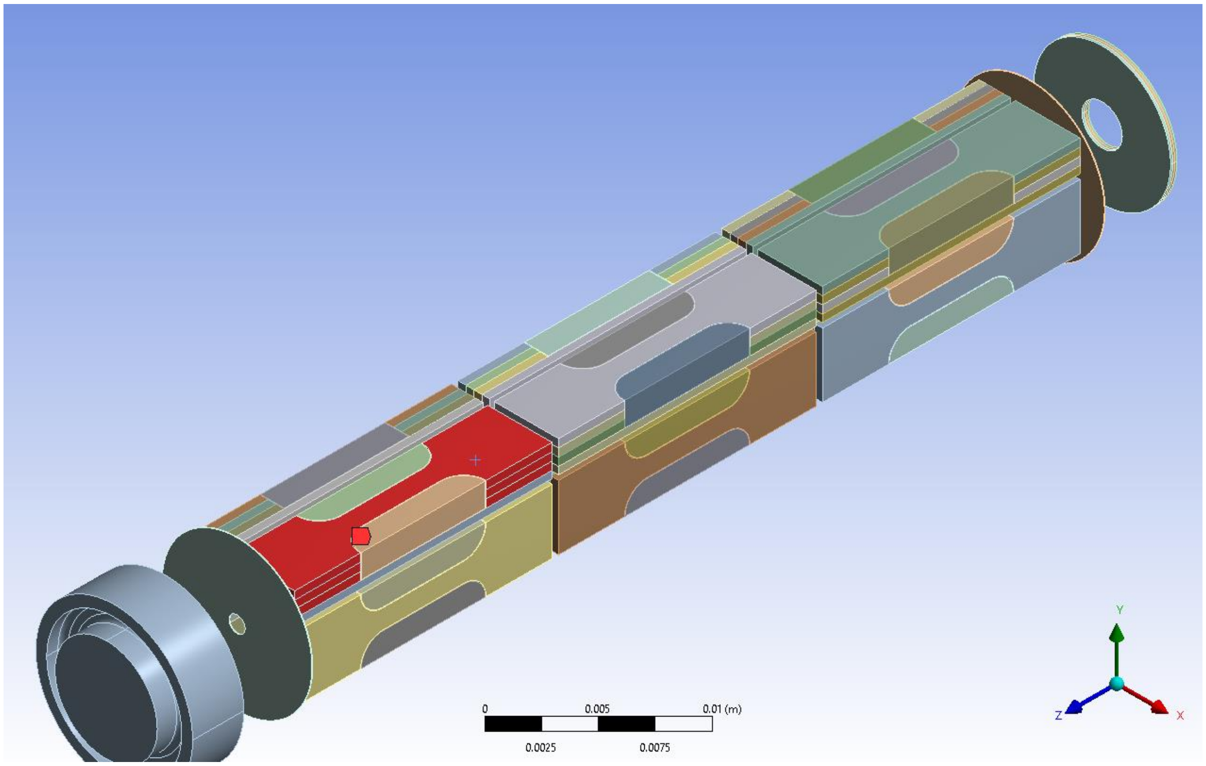


Figure 7. Holder 3 top stack grouping (T3)

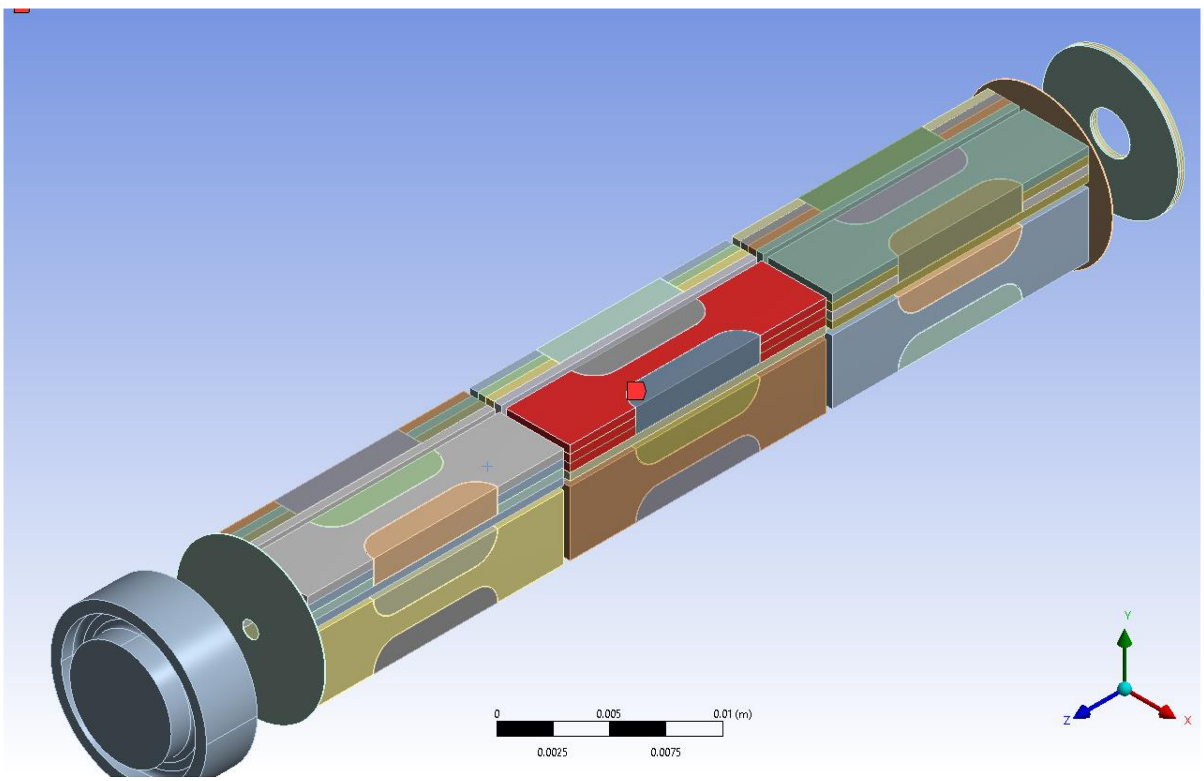


Figure 8. Holder 2 top stack grouping (T2)

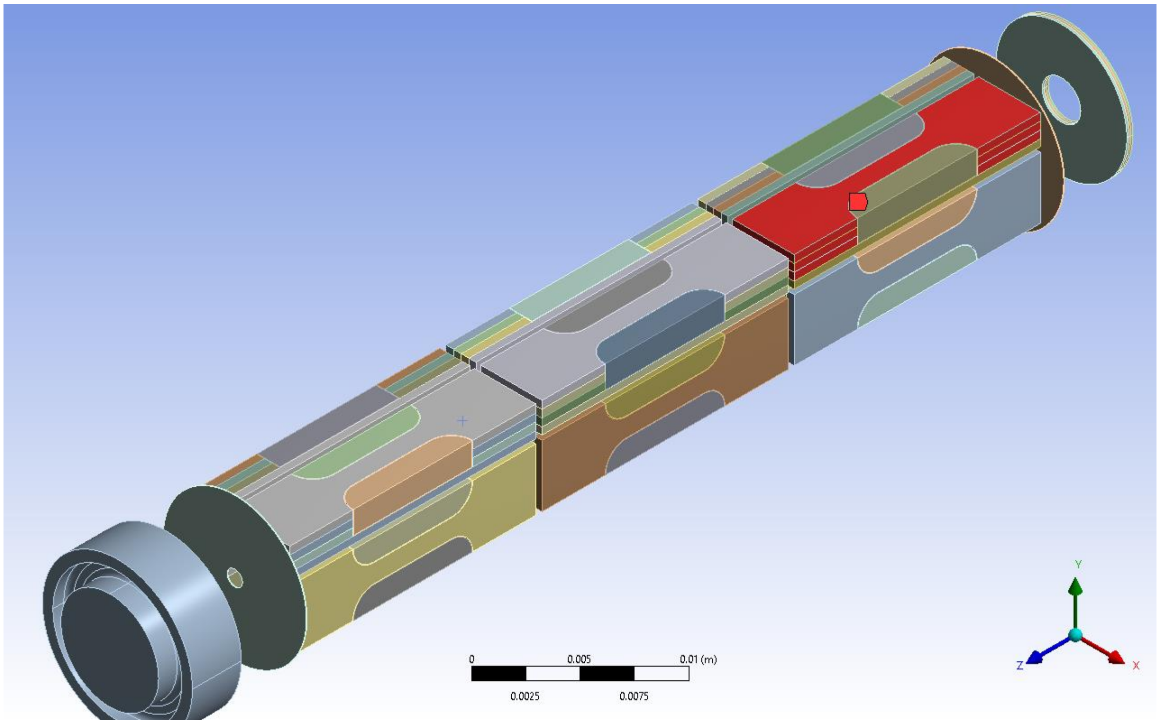


Figure 9. Holder 1 top stack grouping (T1)

The results of a parametric study on holder sizes for TRRH position 6 and HT position 7 are recorded in Table 2-5 and Table 2-6, respectively. In these tables, a row is a rabbit permutation. The OD columns provide the ODs (in mm) of the three holders in a rabbit. The T columns contain temperatures (in °C) that correspond to the red slab regions specified in the preceding three figures. More details are provided in the complete ANSYS reports in APPENDIX A1: Capsule Thermal Reports.

Table 2-5. ANSYS parametric study results—TRRH position 6

Run	Position	OD1 mm	OD2 mm	OD3 mm	T4 °C	T3 °C	T2 °C	T1 °C
61	6	9.30	9.30	9.30	250	248	258	242
62	6	9.15	9.30	9.30	276	249	268	306
63	6	9.45	9.30	9.30	215	246	241	153
64	6	9.30	9.15	9.30	275	258	311	252
65	6	9.30	9.45	9.30	210	230	173	223
66	6	9.30	9.30	9.15	276	313	268	243
67	6	9.30	9.30	9.45	215	159	242	240
68	6	9.18	9.18	9.18	320	317	328	310
69	6	9.42	9.18	9.18	264	313	299	177
70	6	9.18	9.42	9.18	255	284	201	275
71	6	9.42	9.42	9.18	214	283	190	165
72	6	9.18	9.18	9.42	264	184	298	306
73	6	9.42	9.18	9.42	210	182	269	175
74	6	9.18	9.42	9.42	214	172	190	274
75	6	9.42	9.42	9.42	173	171	179	165

Table 2-6. ANSYS parametric study results—HT position 7

Run	Position	OD1 mm	OD2 mm	OD3 mm	T4 °C	T3 °C	T2 °C	T1 °C
61	7	9.30	9.30	9.30	252	249	259	243
62	7	9.15	9.30	9.30	277	250	270	307
63	7	9.45	9.30	9.30	217	247	243	156
64	7	9.30	9.15	9.30	276	260	311	254
65	7	9.30	9.45	9.30	212	231	176	225
66	7	9.30	9.30	9.15	277	313	270	245
67	7	9.30	9.30	9.45	217	162	243	242
68	7	9.18	9.18	9.18	320	317	328	311
69	7	9.42	9.18	9.18	266	313	300	180
70	7	9.18	9.42	9.18	256	284	204	277
71	7	9.42	9.42	9.18	216	283	193	168
72	7	9.18	9.18	9.42	265	186	299	307
73	7	9.42	9.18	9.42	212	184	271	178
74	7	9.18	9.42	9.42	216	174	193	276
75	7	9.42	9.42	9.42	176	173	182	168

Tables like the preceding two were generated for all axial locations in the TRRH and HT facilities, but locations 6 and 7 were, respectively, selected for reporting in this document as these are the intended positions for the rabbits. Because the tables include several internal temperature predictions for all positions of the two irradiation facilities, when available irradiation positions in TRRH or HT are specified, a set of three holder ODs that correspond most closely to a specified irradiation temperature can be selected from the tables. T4, which is the average temperature in the middle position in the stack in the top quadrant provides the fairest representation of the thermal performance of the rabbits. The information in the complete set of tables also allows for a contingency plan of irradiation positions, based on specified holder sizes, in the event the targeted irradiation facility position is occupied. That is, alternate TRRH and HT positions can be chosen for an already-built set of holder ODs to achieve a T4 (i.e., average middle specimen stack temperature) similar to the specified design temperature, allowing for dynamic loading of rabbits in a HFIR cycle based on campaign priority, position availability, and design temperature flexibility.

Note that the results shown in Table 2-5 and Table 2-6 are based on a specimen selection that is slightly different from those used in Figure 3 and Table 2-7. As mentioned above, the ultimate selection of materials supplied for irradiation was uncertain, and the actual selection differed from what was expected when holders were sized and ordered. Follow-up finite element thermal analyses with the specimen types and numbers shown in Figure 3 have shown that changes in T4 predictions were on the order of fractions of percentages (about 1 °C), meaning the design temperature prediction was still well within the allowable temperature range for the campaign (300 °C ± 50 °C). In Table 2-5 and Table 2-6, Run 68 indicates the predicted middle specimen average temperature (T4) for the set of three identical holder OD sizes selected (3 x 9.18 mm).

2.3 TEST MATRIX

Table 2-7 summarizes the different specimen types and numbers that were ultimately produced for irradiation. Fifteen different materials will be studied, including thirteen materials provided by MIT and two materials provided by ORNL. MIT materials include prototype metal with and without nanodispersions (1D carbon nanotube (CNT) or 2D graphene sheets): aluminum, aluminum + 1D CNT, Fe-16Cr-2Si steel, Fe-20Cr-2Si steel, copper, copper + 2D graphene, single crystal nickel, Steel 1 (martensitic steel, Fe-9Cr-1W-0.1C-0.4Ti), Steel 1 + oxides/carbides (O/C), Steel 2 (austenitic steel, Fe-18Cr-8Ni-2W-1Ti), Steel 2 + O/C, nickel, nickel + 1D CNT. OFRAC and Grade 91 materials were provided by ORNL. Each material is planned to be irradiated at each irradiation condition; all irradiations' design target temperature is of 300 ± 50°C with doses of approximately 0.7, 1.4, and 2.1 dpa (approximately one-half, one, and two cycles in HFIR, respectively). A total of six capsules will be irradiated (two capsules per irradiation condition).

Table 2-7. Irradiation test matrix

Capsule ID	**JULI01**	**JULI02**	**JULI03**	**JULI04**	**JULI05**	**JULI06**	
Irradiation temperature (°C)	**300**						
Dose (dpa)	**0.7**		**1.4**		**2.1**		
Materials	**Number of SSJ2 specimens**						***Total***
Al	3	2	3	2	3	2	*15*
Al + CNT	3	2	3	2	3	2	*15*
Cu	3	1	3	1	3	1	*12*
Cu + graphene	3	1	3	1	3	1	*12*
Fe-16Cr-2Si	2	3	2	3	2	3	*15*
Fe-20Cr-2Si	2	3	2	3	2	3	*15*
Grade 91	3	3	3	3	3	3	*18*
Ni	2	3	2	3	2	3	*15*
Ni + CNT	3	2	3	2	3	2	*15*
OFRAC	0	3	0	3	0	3	*9*
Single crystal Ni	2	3	2	3	2	3	*15*
Steel 1	3	2	3	2	3	2	*15*
Steel 1 + oxide/carbide	2	3	2	3	2	3	*15*
Steel 2	2	3	2	3	2	3	*15*
Steel 2 + oxide/carbide	3	2	3	2	3	2	*15*
Total number of specimens	*36*	*36*	*36*	*36*	*36*	*36*	*216*

3. RABBIT CAPSULE ASSEMBLY AND HFIR FABRICATION

Six rabbit capsules, with IDs JULI01 to JULI06, were assembled. Examples of capsule complete parts layout are given by: Figure 10, Figure 11 and Figure 12. The details of each capsule components are shown on the capsule fabrication request sheets provided in Appendix A2. In total, 87 high-resolution digital images of each capsule's components were taken; these are stored electronically, for record keeping purposes.

All the capsule components were dimensionally inspected and cleaned according to HFIR-approved procedures, drawings, and sketches. After assembly of the internal components, the rabbit housings' 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 with helium three times to ensure a pure environment. The chambers were placed inside a glove box, which was also evacuated and backfilled with helium. 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 7.136 MPa 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 the helium leak testing and hydrostatic compression.

Figure 10. Parts layout for capsule JULI04.

Figure 11. First partial parts layout for JULI02

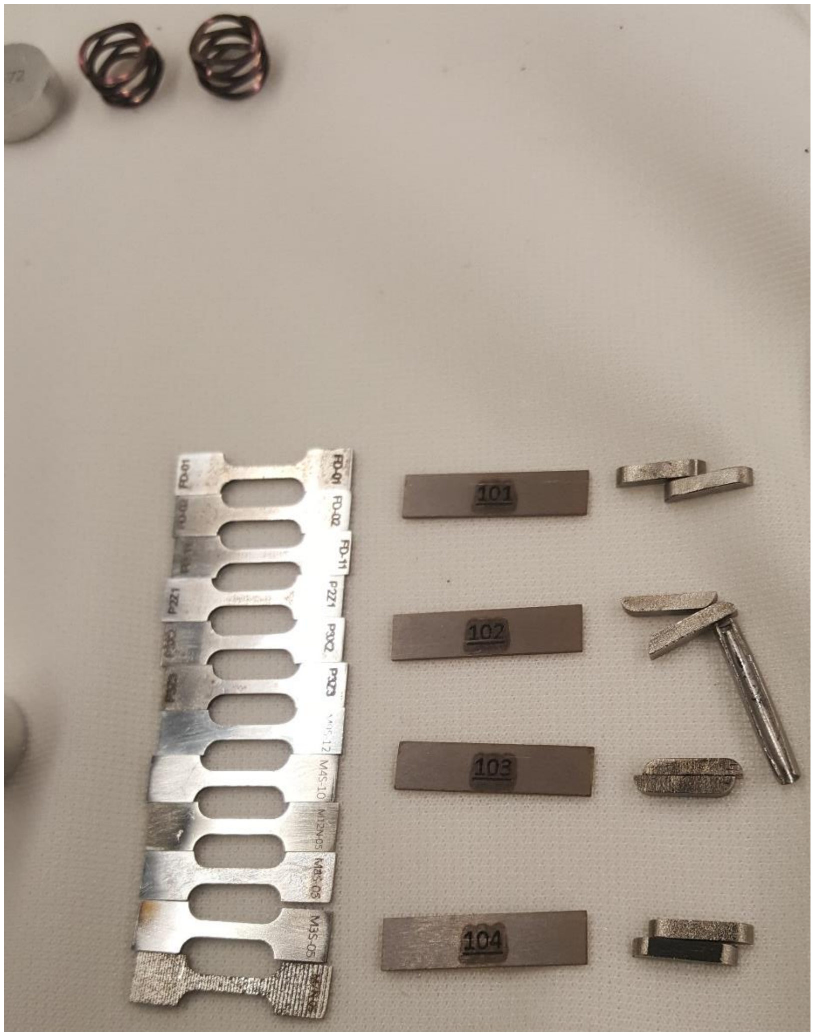


Figure 12. Second partial parts layout for JULI02

4. SUMMARY AND CONCLUSIONS

This work summarizes the capsule design concept and irradiation test matrix for six rabbit capsules, which were successfully assembled and delivered to HFIR. Each rabbit contains tensile specimens from different prototype metals with and without nanodispersion features. The specimens will be evaluated post irradiation to investigate the effects of irradiation on the materials' microstructures and mechanical properties. The rabbits were successfully assembled, welded, evaluated, according HFIR quality assurance. Pictures of the rabbit assembly process are included in this report. Ultimately, the results of this project will be coupled with modeling to understand the mechanism of defects evolution at interfaces in the nanodispersion-strengthened materials under neutron irradiation and will impact the development of new radiation-resistant materials.

5. WORKS CITED

[1] Oak Ridge National Laboratory, "High Flux Isotope Reactor Technical Parameters," [Online]. Available: http://neutrons.ornl.gov/hfir/parameters. [Accessed 27 July 2016].

[2] A. Campbell, W. Porter, Y. Katoh and L. Snead, "Method for analyzing passive silicon carbide thermometry with a continuous dilatometer to determine irradiation temperature," *Nuclear Instruments and Methods in Physics Research B,* vol. 370, pp. 49-58, 2016.

[3] J. L. McDuffee, "Heat Generation Rates for Various Rabbit Materials in the Flux Trap of HFIR," DAC-10-18-RAB02, Rev.0, 2011.

[4] R. H. Howard and K. R. Smith, "Development of a Flexible Design for Irradiation of Miniature Tensile and Charpy Test Specimens in the High Flux Isotope Reactor," ORNL/TM-2018/872, 2018.

[5] Oak Ridge National Laboratory, NEIT, "Target Capsule Housing Assembly," X3E020977A633, Rev. 2, 2018.

[6] Oak Ridge National Laboratory, NEIT, "Target Capsule Housing / End Cap Detail," X3E020977A634, Rev. C, 2018.

[7] J. L. McDuffee, "Heat Transfer Coefficients and Bulk Temperatures for HFIR Rabbit Facilities," DAC-11-01-RAB03, Rev. 0, 2011.

[8] J. L. McDuffee, "Thermophysical Properties for AL6061," DAC-10-13-PROP_AL6061, Rev. 2, 2013.

[9] J. L. McDuffee, "Thermophysical Properties for Molybdenum," DAC-10-11-PROP_MOLY, Rev. 1, 2013.

[10] J. L. McDuffee, "Thermophysical Properties for Flexible Graphite," DAC-11-16_PROP_GRAFOIL Rev. 0, 2013.

[11] J. L. McDuffee, "Thermophysical properties for the 304 Stainless Steel and other 300-series stainless steels," DAC-10-16-PROP_SS304 Rev. 1, 2013.

[12] R. H. Howard, "Thermophysical Properties for F82H Steel," DAC-10-10-PROP_F82H, 2016.

[13] J. L. McDuffee, "Thermophysical Properties for Irradiated SiC," DAC-10-06-PROP_SIC(IRR), Rev. 2, 2013.

[14] J. L. McDuffee, "Thermophysical Properties for Copper," DAC-12-06-PROP_COPPER, Rev.0, 2012.

[15] R. H. Howard, "Thermophysical Properties of Nickel," DAC-13-15-PROP_NICKEL, Rev.1, 2014.

[16] J. L. McDuffee, "Thermophysical Properties for Helium," DAC-10-02-PROP_HELIUM, Rev.0, 2010.

[17] C. Petrie, "Thermal Design Analysis for CNL Non-Optimized Spring Specimen Rabbits," DAC-15-16-CNLN01, Rev.0, 2015.

[18] J. L. McDuffee, "Solve Macros for ANSYS Finite Element Models With Contact Elements," Oak Ridge National Laboratory, Oak Ridge, TN, 2016.

APPENDIX A1: CAPSULE THERMAL REPORTS

CONTENTS

This appendix contains two customized-ANSYS-generated thermal descriptions for the model rabbit at TRRH position 6 and HT position 7, using the holder sizes selected for the actual rabbits. Note that while 9.18 mm OD holders were chosen, that measurement was rounded up from the 9.178 mm (for practicality of manufacture purposes).

Table A-1. Rabbit temperature description, TRRH

```
*************************************************************************
   TEMPERATURE DESIGN SOLUTION GENERAL METAL TENSILE
*************************************************************************
-----------------------------------------------------------------------------
BOUNDARY CONDITIONS

Heat transfer coefficient =  31600. W/m²·°C
Bulk coolant temperature  =    53.0 °C
Holder OD1  = 9.178 mm
Holder OD2  = 9.178 mm
Holder OD3  = 9.178 mm
HFIR HT Axial position 7.
HE fill gas

-----------------------------------------------------------------------------
 HEAT GENERATION
```

Part	Material	Heat Gen. @Midplane (W/kg)	------ Heat Load ----- @Midplane (W)	@Location (W)
1) ENDCAP	AL-6061	32500.	20.2	15.2
3) GRAFOIL.1	GRAFOIL	33700.	0.2	0.2
4) GRAFOIL.2	GRAFOIL	33700.	0.2	0.2
5) GRAFOIL.3	GRAFOIL	33700.	0.2	0.2
6) HOLDER.1	AL-6061	32500.	38.8	33.7
8) ROLLPIN.1	SS304	39300.	10.1	8.7
9) TENSILE_Cu.1	Copper	44200.	8.7	7.5
10) TENSILE_Al.1	AL-6061	32500.	1.9	1.7
11) CHEVRON_Cu.1	Copper	44200.	5.6	4.9
12) CHEVRON_Cu.2	Copper	44200.	5.6	4.9
13) TENSILE_Cu.2	Copper	44200.	8.7	7.5
14) TENSILE_Al.2	AL-6061	32500.	1.9	1.7
15) TENSILE_Cu.3	Copper	44200.	8.7	7.5
16) CHEVRON_Cu.3	Copper	44200.	5.6	4.9
17) CHEVRON_Cu.4	Copper	44200.	5.6	4.9
18) TENSILE_Al.3	AL-6061	32500.	1.9	1.7
19) TENSILE_Cu.4	Copper	44200.	8.7	7.5
20) TENSILE_Al.4	AL-6061	32500.	1.9	1.7
21) CHEVRON_Cu.5	Copper	44200.	5.6	4.9
22) CHEVRON_Cu.6	Copper	44200.	5.6	4.9
23) TENSILE_Cu.5	Copper	44200.	8.7	7.5
24) TENSILE_Al.5	AL-6061	32500.	1.9	1.7
25) TENSILE_30.1	SS304	39300.	6.9	6.0
26) CHEVRON_30.1	SS304	39300.	4.5	3.9
27) CHEVRON_30.2	SS304	39300.	4.5	3.9
28) TENSILE_30.2	SS304	39300.	6.9	6.0
29) THERMOMETRY.1	SiC(Irr)	32900.	3.0	2.6
30) THERMOMETRY.2	SiC(Irr)	32900.	3.0	2.6
31) THERMOMETRY.3	SiC(Irr)	32900.	3.0	2.6
32) THERMOMETRY.4	SiC(Irr)	32900.	3.0	2.6
33) ROLLPIN.2	SS304	39300.	10.1	8.4
34) TENSILE_Ni.1	Nickel	39300.	7.7	6.4
35) TENSILE_41.1	F82H	39300.	6.8	5.6
36) CHEVRON_30.3	SS304	39300.	4.5	3.7
37) CHEVRON_30.4	SS304	39300.	4.5	3.7
38) TENSILE_Ni.2	Nickel	39300.	7.7	6.4
39) TENSILE_41.2	F82H	39300.	6.8	5.6
40) TENSILE_Ni.3	Nickel	39300.	7.7	6.4
41) CHEVRON_30.5	SS304	39300.	4.5	3.7
42) CHEVRON_30.6	SS304	39300.	4.5	3.7
43) TENSILE_30.3	SS304	39300.	6.9	5.7

```
*************************************************************************
   TEMPERATURE DESIGN SOLUTION GENERAL METAL TENSILE
*************************************************************************
```

BOUNDARY CONDITIONS

Heat transfer coefficient = 47100. W/m²·°C
Bulk coolant temperature = 52.0 °C
Holder OD1 = 9.178 mm
Holder OD2 = 9.178 mm
Holder OD3 = 9.178 mm
HFIR TRRH Axial position 6.
HE fill gas

HEAT GENERATION

Part	Material	Heat Gen. @Midplane (W/kg)	------ Heat Load ----- @Midplane (W)	@Location (W)
1) ENDCAP	AL-6061	32500.	20.2	15.4
3) GRAFOIL.1	GRAFOIL	33700.	0.2	0.2
4) GRAFOIL.2	GRAFOIL	33700.	0.2	0.2
5) GRAFOIL.3	GRAFOIL	33700.	0.2	0.2
6) HOLDER.1	AL-6061	32500.	38.8	34.0
8) ROLLPIN.1	SS304	39300.	10.1	8.8
9) TENSILE_Cu.1	Copper	44200.	8.7	7.6
10) TENSILE_Al.1	AL-6061	32500.	1.9	1.7
11) CHEVRON_Cu.1	Copper	44200.	5.6	4.9
12) CHEVRON_Cu.2	Copper	44200.	5.6	4.9
13) TENSILE_Cu.2	Copper	44200.	8.7	7.6
14) TENSILE_Al.2	AL-6061	32500.	1.9	1.7
15) TENSILE_Cu.3	Copper	44200.	8.7	7.6
16) CHEVRON_Cu.3	Copper	44200.	5.6	4.9
17) CHEVRON_Cu.4	Copper	44200.	5.6	4.9
18) TENSILE_Al.3	AL-6061	32500.	1.9	1.7
19) TENSILE_Cu.4	Copper	44200.	8.7	7.6
20) TENSILE_Al.4	AL-6061	32500.	1.9	1.7
21) CHEVRON_Cu.5	Copper	44200.	5.6	4.9
22) CHEVRON_Cu.6	Copper	44200.	5.6	4.9
23) TENSILE_Cu.5	Copper	44200.	8.7	7.6
24) TENSILE_Al.5	AL-6061	32500.	1.9	1.7
25) TENSILE_30.1	SS304	39300.	6.9	6.1
26) CHEVRON_30.1	SS304	39300.	4.5	4.0
27) CHEVRON_30.2	SS304	39300.	4.5	4.0
28) TENSILE_30.2	SS304	39300.	6.9	6.1
29) THERMOMETRY.1	SiC(Irr)	32900.	3.0	2.7
30) THERMOMETRY.2	SiC(Irr)	32900.	3.0	2.7
31) THERMOMETRY.3	SiC(Irr)	32900.	3.0	2.7
32) THERMOMETRY.4	SiC(Irr)	32900.	3.0	2.7
33) ROLLPIN.2	SS304	39300.	10.1	8.5
34) TENSILE_Ni.1	Nickel	39300.	7.7	6.5
35) TENSILE_41.1	F82H	39300.	6.8	5.7
36) CHEVRON_30.3	SS304	39300.	4.5	3.8
37) CHEVRON_30.4	SS304	39300.	4.5	3.8
38) TENSILE_Ni.2	Nickel	39300.	7.7	6.5
39) TENSILE_41.2	F82H	39300.	6.8	5.7
40) TENSILE_Ni.3	Nickel	39300.	7.7	6.5

41) CHEVRON_30.5	SS304	39300.	4.5	3.8
42) CHEVRON_30.6	SS304	39300.	4.5	3.8
43) TENSILE_30.3	SS304	39300.	6.9	5.8
44) TENSILE_Ni.4	Nickel	39300.	7.7	6.5
45) TENSILE_30.4	SS304	39300.	6.9	5.8
46) CHEVRON_30.7	SS304	39300.	4.5	3.8
47) CHEVRON_30.8	SS304	39300.	4.5	3.8
48) TENSILE_Ni.5	Nickel	39300.	7.7	6.5
49) TENSILE_41.3	F82H	39300.	6.8	5.7
50) TENSILE_41.4	F82H	39300.	6.8	5.7
51) CHEVRON_30.9	SS304	39300.	4.5	3.8
52) CHEVRON_30.10	SS304	39300.	4.5	3.8
53) TENSILE_41.5	F82H	39300.	6.8	5.7
54) THERMOMETRY.5	SiC(Irr)	32900.	3.0	2.6
55) THERMOMETRY.6	SiC(Irr)	32900.	3.0	2.6
56) THERMOMETRY.7	SiC(Irr)	32900.	3.0	2.6
57) THERMOMETRY.8	SiC(Irr)	32900.	3.0	2.6
58) ROLLPIN.3	SS304	39300.	10.1	8.1
59) TENSILE_Zr.1	Nickel	39300.	7.7	6.1
60) TENSILE_Zr.2	Nickel	39300.	7.7	6.1
61) CHEVRON_30.11	SS304	39300.	4.5	3.6
62) CHEVRON_30.12	SS304	39300.	4.5	3.6
63) TENSILE_Zr.3	Nickel	39300.	7.7	6.1
64) TENSILE_41.6	F82H	39300.	6.8	5.4
65) TENSILE_41.7	F82H	39300.	6.8	5.4
66) CHEVRON_30.13	SS304	39300.	4.5	3.6
67) CHEVRON_30.14	SS304	39300.	4.5	3.6
68) TENSILE_41.8	F82H	39300.	6.8	5.4
69) TENSILE_Zr.4	Nickel	39300.	7.7	6.1
70) TENSILE_41.9	F82H	39300.	6.8	5.4
71) CHEVRON_30.15	SS304	39300.	4.5	3.6
72) CHEVRON_30.16	SS304	39300.	4.5	3.6
73) TENSILE_Zr.5	Nickel	39300.	7.7	6.1
74) TENSILE_41.10	F82H	39300.	6.8	5.4
75) TENSILE_41.11	F82H	39300.	6.8	5.4
76) CHEVRON_30.17	SS304	39300.	4.5	3.6
77) CHEVRON_30.18	SS304	39300.	4.5	3.6
78) TENSILE_41.12	F82H	39300.	6.8	5.4
79) THERMOMETRY.9	SiC(Irr)	32900.	3.0	2.4
80) THERMOMETRY.10	SiC(Irr)	32900.	3.0	2.4
81) THERMOMETRY.11	SiC(Irr)	32900.	3.0	2.4
82) THERMOMETRY.12	SiC(Irr)	32900.	3.0	2.4
83) SUPPORT_DISK.1	Moly	43300.	1.5	1.3
84) SUPPORT_DISK.2	Moly	43300.	1.5	1.2
85) HOLDER.2	AL-6061	32500.	38.8	32.6
87) HOLDER.3	AL-6061	32500.	38.8	31.1
89) HOUSING	AL-6061	32500.	139.3	117.5
			699.8	586.1

CAPSULE TEMPERATURE SUMMARY

Name	Material	Tavg	Tmin	Tmax	T.025	T.975
1) ENDCAP	AL-6061	81.	79.	83.	79.	82.
3) GRAFOIL.1	GRAFOIL	61.	60.	61.	60.	61.
4) GRAFOIL.2	GRAFOIL	61.	61.	62.	61.	62.

5)	GRAFOIL.3	GRAFOIL	62.	61.	62.	61.	62.
6)	HOLDER.1	AL-6061	291.	282.	295.	288.	294.
8)	ROLLPIN.1	SS304	376.	368.	384.	370.	381.
9)	TENSILE_Cu.1	Copper	310.	308.	313.	309.	313.
10)	TENSILE_Al.1	AL-6061	319.	314.	322.	315.	321.
11)	CHEVRON_Cu.1	Copper	329.	327.	329.	328.	329.
12)	CHEVRON_Cu.2	Copper	311.	310.	311.	310.	311.
13)	TENSILE_Cu.2	Copper	328.	324.	330.	325.	330.
14)	TENSILE_Al.2	AL-6061	304.	302.	308.	302.	307.
15)	TENSILE_Cu.3	Copper	316.	312.	318.	313.	318.
16)	CHEVRON_Cu.3	Copper	326.	325.	327.	326.	327.
17)	CHEVRON_Cu.4	Copper	310.	309.	310.	309.	310.
18)	TENSILE_Al.3	AL-6061	319.	313.	323.	314.	323.
19)	TENSILE_Cu.4	Copper	311.	309.	314.	309.	314.
20)	TENSILE_Al.4	AL-6061	320.	315.	323.	316.	322.
21)	CHEVRON_Cu.5	Copper	329.	328.	330.	329.	330.
22)	CHEVRON_Cu.6	Copper	312.	311.	312.	311.	312.
23)	TENSILE_Cu.5	Copper	329.	325.	331.	326.	331.
24)	TENSILE_Al.5	AL-6061	307.	303.	312.	304.	311.
25)	TENSILE_30.1	SS304	323.	305.	333.	309.	331.
26)	CHEVRON_30.1	SS304	333.	317.	343.	324.	341.
27)	CHEVRON_30.2	SS304	311.	303.	322.	306.	319.
28)	TENSILE_30.2	SS304	334.	303.	348.	313.	345.
29)	THERMOMETRY.1	SiC(Irr)	339.	297.	370.	307.	363.
30)	THERMOMETRY.2	SiC(Irr)	332.	298.	363.	306.	353.
31)	THERMOMETRY.3	SiC(Irr)	327.	296.	362.	305.	352.
32)	THERMOMETRY.4	SiC(Irr)	334.	298.	365.	307.	355.
33)	ROLLPIN.2	SS304	388.	382.	395.	384.	392.
34)	TENSILE_Ni.1	Nickel	315.	309.	321.	310.	319.
35)	TENSILE_41.1	F82H	329.	310.	337.	316.	336.
36)	CHEVRON_30.3	SS304	335.	319.	345.	326.	343.
37)	CHEVRON_30.4	SS304	314.	307.	324.	309.	321.
38)	TENSILE_Ni.2	Nickel	339.	319.	347.	325.	346.
39)	TENSILE_41.2	F82H	315.	307.	323.	310.	321.
40)	TENSILE_Ni.3	Nickel	331.	315.	338.	319.	337.
41)	CHEVRON_30.5	SS304	336.	320.	347.	327.	344.
42)	CHEVRON_30.6	SS304	314.	307.	324.	309.	321.
43)	TENSILE_30.3	SS304	340.	306.	354.	318.	351.
44)	TENSILE_Ni.4	Nickel	315.	309.	321.	310.	319.
45)	TENSILE_30.4	SS304	330.	307.	340.	315.	338.
46)	CHEVRON_30.7	SS304	336.	318.	345.	327.	343.
47)	CHEVRON_30.8	SS304	314.	307.	325.	309.	322.
48)	TENSILE_Ni.5	Nickel	340.	320.	350.	326.	349.
49)	TENSILE_41.3	F82H	314.	305.	321.	308.	319.
50)	TENSILE_41.4	F82H	329.	310.	337.	315.	335.
51)	CHEVRON_30.9	SS304	335.	319.	344.	326.	342.
52)	CHEVRON_30.10	SS304	313.	306.	323.	308.	320.
53)	TENSILE_41.5	F82H	337.	309.	349.	318.	347.
54)	THERMOMETRY.5	SiC(Irr)	342.	298.	375.	308.	367.
55)	THERMOMETRY.6	SiC(Irr)	343.	299.	377.	309.	367.
56)	THERMOMETRY.7	SiC(Irr)	344.	298.	378.	309.	369.
57)	THERMOMETRY.8	SiC(Irr)	344.	298.	377.	309.	368.
58)	ROLLPIN.3	SS304	377.	372.	384.	374.	382.
59)	TENSILE_Zr.1	Nickel	309.	304.	315.	305.	314.
60)	TENSILE_Zr.2	Nickel	323.	309.	329.	313.	329.
61)	CHEVRON_30.11	SS304	328.	313.	338.	320.	336.
62)	CHEVRON_30.12	SS304	308.	301.	318.	303.	315.
63)	TENSILE_Zr.3	Nickel	331.	313.	340.	319.	339.
64)	TENSILE_41.6	F82H	308.	299.	315.	301.	313.
65)	TENSILE_41.7	F82H	322.	304.	331.	309.	329.

66) CHEVRON_30.13	SS304	328.	313.	338.	319.	335.
67) CHEVRON_30.14	SS304	307.	300.	317.	302.	314.
68) TENSILE_41.8	F82H	331.	303.	343.	311.	341.
69) TENSILE_Zr.4	Nickel	308.	302.	313.	303.	312.
70) TENSILE_41.9	F82H	322.	303.	330.	309.	328.
71) CHEVRON_30.15	SS304	327.	311.	337.	318.	335.
72) CHEVRON_30.16	SS304	307.	300.	317.	302.	313.
73) TENSILE_Zr.5	Nickel	331.	311.	340.	317.	338.
74) TENSILE_41.10	F82H	308.	299.	316.	301.	314.
75) TENSILE_41.11	F82H	322.	304.	331.	309.	330.
76) CHEVRON_30.17	SS304	327.	312.	337.	318.	335.
77) CHEVRON_30.18	SS304	318.	306.	326.	311.	324.
78) TENSILE_41.12	F82H	331.	304.	342.	312.	340.
79) THERMOMETRY.9	SiC(Irr)	336.	293.	366.	305.	358.
80) THERMOMETRY.10	SiC(Irr)	335.	293.	368.	303.	358.
81) THERMOMETRY.11	SiC(Irr)	335.	291.	368.	302.	359.
82) THERMOMETRY.12	SiC(Irr)	335.	292.	367.	302.	358.
83) SUPPORT_DISK.1	Moly	309.	287.	328.	294.	326.
84) SUPPORT_DISK.2	Moly	287.	273.	294.	280.	293.
85) HOLDER.2	AL-6061	291.	282.	295.	288.	294.
87) HOLDER.3	AL-6061	286.	276.	290.	283.	289.
89) HOUSING	AL-6061	58.	54.	64.	54.	60.

PROPERTY SUMMARY AT THE AVERAGE PART TEMPERATURE

Name	Material	Thermal Cond. (W/m·ºC)	Thermal Exp. Coeff. (µm/m·°C)	Emis (---)
1) ENDCAP	AL-6061	169.124	0.00	0.050
3) GRAFOIL.1	GRAFOIL	38.000	1.00	0.500
4) GRAFOIL.2	GRAFOIL	38.000	1.00	0.500
5) GRAFOIL.3	GRAFOIL	38.000	1.00	0.500
6) HOLDER.1	AL-6061	176.000	25.35	0.056
8) ROLLPIN.1	SS304	20.484	0.00	0.143
9) TENSILE_Cu.1	Copper	380.160	0.00	0.032
10) TENSILE_Al.1	AL-6061	176.000	0.00	0.058
11) CHEVRON_Cu.1	Copper	378.905	0.00	0.032
12) CHEVRON_Cu.2	Copper	380.138	0.00	0.032
13) TENSILE_Cu.2	Copper	378.955	0.00	0.032
14) TENSILE_Al.2	AL-6061	176.000	0.00	0.057
15) TENSILE_Cu.3	Copper	379.795	0.00	0.032
16) CHEVRON_Cu.3	Copper	379.050	0.00	0.032
17) CHEVRON_Cu.4	Copper	380.220	0.00	0.032
18) TENSILE_Al.3	AL-6061	176.000	0.00	0.058
19) TENSILE_Cu.4	Copper	380.097	0.00	0.032
20) TENSILE_Al.4	AL-6061	176.000	0.00	0.058
21) CHEVRON_Cu.5	Copper	378.854	0.00	0.032
22) CHEVRON_Cu.6	Copper	380.079	0.00	0.032
23) TENSILE_Cu.5	Copper	378.886	0.00	0.032
24) TENSILE_Al.5	AL-6061	176.000	0.00	0.057
25) TENSILE_30.1	SS304	19.747	0.00	0.143
26) CHEVRON_30.1	SS304	19.888	0.00	0.143
27) CHEVRON_30.2	SS304	19.581	0.00	0.143
28) TENSILE_30.2	SS304	19.902	0.00	0.143
29) THERMOMETRY.1	SiC(Irr)	4.986	3.38	0.900
30) THERMOMETRY.2	SiC(Irr)	4.988	3.36	0.900
31) THERMOMETRY.3	SiC(Irr)	4.989	3.34	0.900

32)	THERMOMETRY.4	SiC(Irr)	4.987	3.36	0.900
33)	ROLLPIN.2	SS304	20.653	0.00	0.143
34)	TENSILE_Ni.1	Nickel	66.412	0.00	0.185
35)	TENSILE_41.1	F82H	33.753	11.33	0.143
36)	CHEVRON_30.3	SS304	19.917	0.00	0.143
37)	CHEVRON_30.4	SS304	19.618	0.00	0.143
38)	TENSILE_Ni.2	Nickel	64.945	0.00	0.185
39)	TENSILE_41.2	F82H	33.783	11.27	0.143
40)	TENSILE_Ni.3	Nickel	65.392	0.00	0.185
41)	CHEVRON_30.5	SS304	19.930	0.00	0.143
42)	CHEVRON_30.6	SS304	19.620	0.00	0.143
43)	TENSILE_30.3	SS304	19.980	0.00	0.143
44)	TENSILE_Ni.4	Nickel	66.399	0.00	0.185
45)	TENSILE_30.4	SS304	19.849	0.00	0.143
46)	CHEVRON_30.7	SS304	19.924	0.00	0.143
47)	CHEVRON_30.8	SS304	19.619	0.00	0.143
48)	TENSILE_Ni.5	Nickel	64.846	0.00	0.185
49)	TENSILE_41.3	F82H	33.787	11.26	0.143
50)	TENSILE_41.4	F82H	33.754	11.33	0.143
51)	CHEVRON_30.9	SS304	19.910	0.00	0.143
52)	CHEVRON_30.10	SS304	19.607	0.00	0.143
53)	TENSILE_41.5	F82H	33.735	11.37	0.143
54)	THERMOMETRY.5	SiC(Irr)	4.985	3.39	0.900
55)	THERMOMETRY.6	SiC(Irr)	4.985	3.39	0.900
56)	THERMOMETRY.7	SiC(Irr)	4.984	3.39	0.900
57)	THERMOMETRY.8	SiC(Irr)	4.984	3.39	0.900
58)	ROLLPIN.3	SS304	20.505	0.00	0.143
59)	TENSILE_Zr.1	Nickel	66.757	0.00	0.185
60)	TENSILE_Zr.2	Nickel	65.851	0.00	0.185
61)	CHEVRON_30.11	SS304	19.820	0.00	0.143
62)	CHEVRON_30.12	SS304	19.533	0.00	0.143
63)	TENSILE_Zr.3	Nickel	65.349	0.00	0.185
64)	TENSILE_41.6	F82H	33.800	11.23	0.143
65)	TENSILE_41.7	F82H	33.768	11.30	0.143
66)	CHEVRON_30.13	SS304	19.816	0.00	0.143
67)	CHEVRON_30.14	SS304	19.519	0.00	0.143
68)	TENSILE_41.8	F82H	33.750	11.34	0.143
69)	TENSILE_Zr.4	Nickel	66.861	0.00	0.185
70)	TENSILE_41.9	F82H	33.769	11.30	0.143
71)	CHEVRON_30.15	SS304	19.805	0.00	0.143
72)	CHEVRON_30.16	SS304	19.514	0.00	0.143
73)	TENSILE_Zr.5	Nickel	65.395	0.00	0.185
74)	TENSILE_41.10	F82H	33.800	11.23	0.143
75)	TENSILE_41.11	F82H	33.768	11.30	0.143
76)	CHEVRON_30.17	SS304	19.805	0.00	0.143
77)	CHEVRON_30.18	SS304	19.679	0.00	0.143
78)	TENSILE_41.12	F82H	33.749	11.34	0.143
79)	THERMOMETRY.9	SiC(Irr)	4.987	3.37	0.900
80)	THERMOMETRY.10	SiC(Irr)	4.987	3.37	0.900
81)	THERMOMETRY.11	SiC(Irr)	4.987	3.37	0.900
82)	THERMOMETRY.12	SiC(Irr)	4.987	3.37	0.900
83)	SUPPORT_DISK.1	Moly	126.740	0.00	0.058
84)	SUPPORT_DISK.2	Moly	127.582	0.00	0.056
85)	HOLDER.2	AL-6061	176.000	25.35	0.056
87)	HOLDER.3	AL-6061	176.000	25.30	0.056
89)	HOUSING	AL-6061	166.476	24.21	0.050

CONTACT SUMMARY FOR CONTACT ID 97: HOLDER.1 To HOUSING
Contact surface material: AL-6061

```
   Interstitial gas:             Helium
   Effective surface roughness:    2.263 µm
   Effective asperity slope:       0.214 rad
   Effective microhardness:        1.220 GPa

                                         Average      Minimum      Maximum
                                       ------------ ------------ ------------
   ~~~~~~~~~~~ direct results ~~~~~~~~~~
   Contact status                              1.000        1.000        1.000
   Contact temperature (°C)                  290.018      281.887      292.989
   Target temperature (°C)                    59.870       57.426       62.830
   Geometric gas gap (µm)                    170.122       29.499      170.614
   Contact pressure (MPa)                      0.000        0.000        0.000
   Gap conduction heat flux (kW/m²)          327.184      308.444     3896.325
   Radiation heat flux (kW/m²)                 0.000        0.000        0.000
   Contact conduction heat flux (kW/m²)        0.000        0.000        0.000
   Total heat flux (kW/m²)                   327.184      308.444     3896.325
   Thermal contact conductance (W/m²·C)     1422.921     1372.260    17183.894
   ~~~~~~~~~~ derived results ~~~~~~~~~~
   Effective gas gap (µm)                    143.169        8.878      144.187
   Contact thermal jump distance (µm)          1.520        1.504        1.525
   Target thermal jump distance (µm)           1.349        1.336        1.353
   Effective contact pressure (MPa)            0.000        0.000        0.000
   Pressure index                             13.534       13.534       13.534
   Gas thermal conductivity (W/m·°C)           0.202        0.201        0.203
   Solid spot conductance (W/m²·C)             0.000        0.000        0.000
   Gas gap conductance (W/m²·C)             1422.161     1372.016    17118.766

   Contact status codes:
    ---------------------------------------------
    0=open/no heat transfer, 1=near-field contact
    2=closed and sliding,    3=closed and sticking

--------------------------------------------------------------------------------
CONTACT SUMMARY FOR CONTACT ID 99: HOLDER.2 To HOUSING
   Contact surface material:      AL-6061
   Target surface material:       AL-6061
   Interstitial gas:               Helium
   Effective surface roughness:    2.263 µm
   Effective asperity slope:       0.214 rad
   Effective microhardness:        1.220 GPa

                                         Average      Minimum      Maximum
                                       ------------ ------------ ------------
   ~~~~~~~~~~~ direct results ~~~~~~~~~~
   Contact status                              1.000        1.000        1.000
   Contact temperature (°C)                  290.182      281.742      291.897
   Target temperature (°C)                    60.136       59.964       62.998
   Geometric gas gap (µm)                    170.122       29.499      170.500
   Contact pressure (MPa)                      0.000        0.000        0.000
   Gap conduction heat flux (kW/m²)          327.047      308.338     3826.906
   Radiation heat flux (kW/m²)                 0.000        0.000        0.000
   Contact conduction heat flux (kW/m²)        0.000        0.000        0.000
   Total heat flux (kW/m²)                   327.047      308.338     3826.906
   Thermal contact conductance (W/m²·C)     1423.336     1371.891    17201.663
   ~~~~~~~~~~ derived results ~~~~~~~~~~
   Effective gas gap (µm)                    143.177        8.878      144.191
   Contact thermal jump distance (µm)          1.521        1.503        1.526
   Target thermal jump distance (µm)           1.350        1.341        1.353
   Effective contact pressure (MPa)            0.000        0.000        0.000
```

```
   Pressure index                              13.534       13.534       13.534
   Gas thermal conductivity (W/m·°C)            0.202        0.201        0.203
   Solid spot conductance (W/m²·C)              0.000        0.000        0.000
   Gas gap conductance (W/m²·C)              1422.746     1371.660    17128.889

   Contact status codes:
    ---------------------------------------------
    0=open/no heat transfer, 1=near-field contact
    2=closed and sliding,    3=closed and sticking

-------------------------------------------------------------------------------
CONTACT SUMMARY FOR CONTACT ID 101: HOLDER.3 To HOUSING
   Contact surface material:       AL-6061
   Target surface material:        AL-6061
   Interstitial gas:                Helium
   Effective surface roughness:      2.263 µm
   Effective asperity slope:         0.214 rad
   Effective microhardness:          1.220 GPa

                                              Average      Minimum      Maximum
                                         ------------ ------------ ------------
   ~~~~~~~~~~~ direct results ~~~~~~~~~~
   Contact status                               1.000        1.000        1.000
   Contact temperature (°C)                   284.677      275.757      287.691
   Target temperature (°C)                     59.571       57.019       62.777
   Geometric gas gap (µm)                     170.122       29.499      170.584
   Contact pressure (MPa)                       0.000        0.000        0.000
   Gap conduction heat flux (kW/m²)           317.306      301.166     3757.197
   Radiation heat flux (kW/m²)                  0.000        0.000        0.000
   Contact conduction heat flux (kW/m²)         0.000        0.000        0.000
   Total heat flux (kW/m²)                    317.306      301.166     3757.197
   Thermal contact conductance (W/m²·C)      1410.850     1358.146    17172.062
   ~~~~~~~~~~ derived results ~~~~~~~~~~
   Effective gas gap (µm)                     143.807        8.878      144.614
   Contact thermal jump distance (µm)           1.505        1.480        1.514
   Target thermal jump distance (µm)            1.338        1.320        1.345
   Effective contact pressure (MPa)             0.000        0.000        0.000
   Pressure index                              13.534       13.534       13.534
   Gas thermal conductivity (W/m·°C)            0.201        0.200        0.202
   Solid spot conductance (W/m²·C)              0.000        0.000        0.000
   Gas gap conductance (W/m²·C)              1409.969     1356.935    17111.700

   Contact status codes:
    ---------------------------------------------
    0=open/no heat transfer, 1=near-field contact
    2=closed and sliding,    3=closed and sticking
```

Table A-2. Rabbit temperature description, HT

```
*************************************************************************
   TEMPERATURE DESIGN SOLUTION GENERAL METAL TENSILE
*************************************************************************
-----------------------------------------------------------------------------
BOUNDARY CONDITIONS

Heat transfer coefficient =  31600. W/m²·°C
Bulk coolant temperature  =    53.0 °C
Holder OD1  = 9.178 mm
Holder OD2  = 9.178 mm
Holder OD3  = 9.178 mm
HFIR HT Axial position 7.
HE fill gas

-----------------------------------------------------------------------------
HEAT GENERATION
```

Part	Material	Heat Gen. @Midplane (W/kg)	------ Heat Load ----- @Midplane (W)	@Location (W)
1) ENDCAP	AL-6061	32500.	20.2	15.2
3) GRAFOIL.1	GRAFOIL	33700.	0.2	0.2
4) GRAFOIL.2	GRAFOIL	33700.	0.2	0.2
5) GRAFOIL.3	GRAFOIL	33700.	0.2	0.2
6) HOLDER.1	AL-6061	32500.	38.8	33.7
8) ROLLPIN.1	SS304	39300.	10.1	8.7
9) TENSILE_Cu.1	Copper	44200.	8.7	7.5
10) TENSILE_Al.1	AL-6061	32500.	1.9	1.7
11) CHEVRON_Cu.1	Copper	44200.	5.6	4.9
12) CHEVRON_Cu.2	Copper	44200.	5.6	4.9
13) TENSILE_Cu.2	Copper	44200.	8.7	7.5
14) TENSILE_Al.2	AL-6061	32500.	1.9	1.7
15) TENSILE_Cu.3	Copper	44200.	8.7	7.5
16) CHEVRON_Cu.3	Copper	44200.	5.6	4.9
17) CHEVRON_Cu.4	Copper	44200.	5.6	4.9
18) TENSILE_Al.3	AL-6061	32500.	1.9	1.7
19) TENSILE_Cu.4	Copper	44200.	8.7	7.5
20) TENSILE_Al.4	AL-6061	32500.	1.9	1.7
21) CHEVRON_Cu.5	Copper	44200.	5.6	4.9
22) CHEVRON_Cu.6	Copper	44200.	5.6	4.9
23) TENSILE_Cu.5	Copper	44200.	8.7	7.5
24) TENSILE_Al.5	AL-6061	32500.	1.9	1.7
25) TENSILE_30.1	SS304	39300.	6.9	6.0
26) CHEVRON_30.1	SS304	39300.	4.5	3.9
27) CHEVRON_30.2	SS304	39300.	4.5	3.9
28) TENSILE_30.2	SS304	39300.	6.9	6.0
29) THERMOMETRY.1	SiC(Irr)	32900.	3.0	2.6
30) THERMOMETRY.2	SiC(Irr)	32900.	3.0	2.6
31) THERMOMETRY.3	SiC(Irr)	32900.	3.0	2.6
32) THERMOMETRY.4	SiC(Irr)	32900.	3.0	2.6
33) ROLLPIN.2	SS304	39300.	10.1	8.4
34) TENSILE_Ni.1	Nickel	39300.	7.7	6.4
35) TENSILE_41.1	F82H	39300.	6.8	5.6
36) CHEVRON_30.3	SS304	39300.	4.5	3.7
37) CHEVRON_30.4	SS304	39300.	4.5	3.7
38) TENSILE_Ni.2	Nickel	39300.	7.7	6.4
39) TENSILE_41.2	F82H	39300.	6.8	5.6
40) TENSILE_Ni.3	Nickel	39300.	7.7	6.4
41) CHEVRON_30.5	SS304	39300.	4.5	3.7
42) CHEVRON_30.6	SS304	39300.	4.5	3.7
43) TENSILE_30.3	SS304	39300.	6.9	5.7

44) TENSILE_Ni.4	Nickel	39300.	7.7	6.4
45) TENSILE_30.4	SS304	39300.	6.9	5.7
46) CHEVRON_30.7	SS304	39300.	4.5	3.7
47) CHEVRON_30.8	SS304	39300.	4.5	3.7
48) TENSILE_Ni.5	Nickel	39300.	7.7	6.4
49) TENSILE_41.3	F82H	39300.	6.8	5.6
50) TENSILE_41.4	F82H	39300.	6.8	5.6
51) CHEVRON_30.9	SS304	39300.	4.5	3.7
52) CHEVRON_30.10	SS304	39300.	4.5	3.7
53) TENSILE_41.5	F82H	39300.	6.8	5.6
54) THERMOMETRY.5	SiC(Irr)	32900.	3.0	2.5
55) THERMOMETRY.6	SiC(Irr)	32900.	3.0	2.5
56) THERMOMETRY.7	SiC(Irr)	32900.	3.0	2.5
57) THERMOMETRY.8	SiC(Irr)	32900.	3.0	2.5
58) ROLLPIN.3	SS304	39300.	10.1	8.0
59) TENSILE_Zr.1	Nickel	39300.	7.7	6.1
60) TENSILE_Zr.2	Nickel	39300.	7.7	6.1
61) CHEVRON_30.11	SS304	39300.	4.5	3.6
62) CHEVRON_30.12	SS304	39300.	4.5	3.6
63) TENSILE_Zr.3	Nickel	39300.	7.7	6.1
64) TENSILE_41.6	F82H	39300.	6.8	5.4
65) TENSILE_41.7	F82H	39300.	6.8	5.4
66) CHEVRON_30.13	SS304	39300.	4.5	3.6
67) CHEVRON_30.14	SS304	39300.	4.5	3.6
68) TENSILE_41.8	F82H	39300.	6.8	5.4
69) TENSILE_Zr.4	Nickel	39300.	7.7	6.1
70) TENSILE_41.9	F82H	39300.	6.8	5.4
71) CHEVRON_30.15	SS304	39300.	4.5	3.6
72) CHEVRON_30.16	SS304	39300.	4.5	3.6
73) TENSILE_Zr.5	Nickel	39300.	7.7	6.1
74) TENSILE_41.10	F82H	39300.	6.8	5.4
75) TENSILE_41.11	F82H	39300.	6.8	5.4
76) CHEVRON_30.17	SS304	39300.	4.5	3.6
77) CHEVRON_30.18	SS304	39300.	4.5	3.6
78) TENSILE_41.12	F82H	39300.	6.8	5.4
79) THERMOMETRY.9	SiC(Irr)	32900.	3.0	2.4
80) THERMOMETRY.10	SiC(Irr)	32900.	3.0	2.4
81) THERMOMETRY.11	SiC(Irr)	32900.	3.0	2.4
82) THERMOMETRY.12	SiC(Irr)	32900.	3.0	2.4
83) SUPPORT_DISK.1	Moly	43300.	1.5	1.3
84) SUPPORT_DISK.2	Moly	43300.	1.5	1.1
85) HOLDER.2	AL-6061	32500.	38.8	32.2
87) HOLDER.3	AL-6061	32500.	38.8	30.7
89) HOUSING	AL-6061	32500.	139.3	116.2
			699.8	579.4

CAPSULE TEMPERATURE SUMMARY

Name	Material	Tavg	Tmin	Tmax	T.025	T.975
1) ENDCAP	AL-6061	83.	81.	85.	81.	84.
3) GRAFOIL.1	GRAFOIL	63.	63.	64.	63.	64.
4) GRAFOIL.2	GRAFOIL	64.	64.	64.	64.	64.
5) GRAFOIL.3	GRAFOIL	64.	64.	65.	64.	65.
6) HOLDER.1	AL-6061	292.	283.	296.	289.	295.
8) ROLLPIN.1	SS304	376.	368.	385.	371.	381.
9) TENSILE_Cu.1	Copper	311.	309.	314.	310.	314.
10) TENSILE_Al.1	AL-6061	320.	315.	323.	316.	322.
11) CHEVRON_Cu.1	Copper	329.	328.	330.	329.	330.
12) CHEVRON_Cu.2	Copper	312.	311.	312.	311.	312.

13)	TENSILE_Cu.2	Copper	329.	324.	331.	326.	331.
14)	TENSILE_Al.2	AL-6061	305.	303.	309.	303.	308.
15)	TENSILE_Cu.3	Copper	317.	313.	319.	314.	319.
16)	CHEVRON_Cu.3	Copper	327.	326.	328.	326.	328.
17)	CHEVRON_Cu.4	Copper	311.	310.	311.	310.	311.
18)	TENSILE_Al.3	AL-6061	320.	314.	324.	315.	323.
19)	TENSILE_Cu.4	Copper	312.	310.	315.	310.	315.
20)	TENSILE_Al.4	AL-6061	321.	316.	324.	317.	323.
21)	CHEVRON_Cu.5	Copper	330.	329.	331.	330.	331.
22)	CHEVRON_Cu.6	Copper	313.	312.	313.	312.	313.
23)	TENSILE_Cu.5	Copper	330.	325.	332.	327.	332.
24)	TENSILE_Al.5	AL-6061	308.	304.	313.	305.	312.
25)	TENSILE_30.1	SS304	324.	306.	334.	310.	331.
26)	CHEVRON_30.1	SS304	334.	318.	343.	325.	341.
27)	CHEVRON_30.2	SS304	312.	304.	322.	307.	320.
28)	TENSILE_30.2	SS304	335.	304.	348.	314.	346.
29)	THERMOMETRY.1	SiC(Irr)	340.	298.	370.	308.	363.
30)	THERMOMETRY.2	SiC(Irr)	333.	299.	364.	307.	353.
31)	THERMOMETRY.3	SiC(Irr)	328.	297.	362.	306.	352.
32)	THERMOMETRY.4	SiC(Irr)	334.	299.	365.	308.	355.
33)	ROLLPIN.2	SS304	388.	382.	395.	384.	392.
34)	TENSILE_Ni.1	Nickel	315.	309.	321.	311.	320.
35)	TENSILE_41.1	F82H	330.	311.	338.	317.	336.
36)	CHEVRON_30.3	SS304	336.	320.	345.	327.	343.
37)	CHEVRON_30.4	SS304	315.	308.	325.	310.	322.
38)	TENSILE_Ni.2	Nickel	339.	320.	348.	326.	347.
39)	TENSILE_41.2	F82H	316.	308.	323.	310.	321.
40)	TENSILE_Ni.3	Nickel	331.	316.	339.	320.	337.
41)	CHEVRON_30.5	SS304	337.	321.	347.	328.	344.
42)	CHEVRON_30.6	SS304	315.	308.	325.	310.	322.
43)	TENSILE_30.3	SS304	340.	307.	354.	318.	351.
44)	TENSILE_Ni.4	Nickel	316.	309.	322.	311.	320.
45)	TENSILE_30.4	SS304	331.	307.	340.	316.	338.
46)	CHEVRON_30.7	SS304	336.	319.	346.	327.	344.
47)	CHEVRON_30.8	SS304	315.	308.	325.	310.	322.
48)	TENSILE_Ni.5	Nickel	341.	320.	350.	326.	349.
49)	TENSILE_41.3	F82H	314.	306.	322.	308.	320.
50)	TENSILE_41.4	F82H	329.	311.	338.	316.	336.
51)	CHEVRON_30.9	SS304	335.	320.	345.	326.	343.
52)	CHEVRON_30.10	SS304	314.	307.	324.	309.	321.
53)	TENSILE_41.5	F82H	338.	310.	350.	319.	348.
54)	THERMOMETRY.5	SiC(Irr)	342.	299.	375.	309.	367.
55)	THERMOMETRY.6	SiC(Irr)	343.	300.	377.	310.	367.
56)	THERMOMETRY.7	SiC(Irr)	345.	299.	378.	310.	369.
57)	THERMOMETRY.8	SiC(Irr)	345.	299.	377.	310.	368.
58)	ROLLPIN.3	SS304	377.	371.	383.	373.	381.
59)	TENSILE_Zr.1	Nickel	310.	304.	315.	305.	314.
60)	TENSILE_Zr.2	Nickel	323.	309.	330.	313.	329.
61)	CHEVRON_30.11	SS304	329.	313.	338.	320.	336.
62)	CHEVRON_30.12	SS304	308.	301.	318.	304.	315.
63)	TENSILE_Zr.3	Nickel	332.	313.	340.	319.	339.
64)	TENSILE_41.6	F82H	308.	300.	315.	302.	313.
65)	TENSILE_41.7	F82H	322.	304.	331.	309.	329.
66)	CHEVRON_30.13	SS304	328.	313.	338.	319.	336.
67)	CHEVRON_30.14	SS304	307.	300.	317.	303.	314.
68)	TENSILE_41.8	F82H	331.	303.	343.	312.	341.
69)	TENSILE_Zr.4	Nickel	308.	302.	314.	303.	312.
70)	TENSILE_41.9	F82H	322.	303.	330.	309.	328.
71)	CHEVRON_30.15	SS304	328.	311.	337.	319.	335.
72)	CHEVRON_30.16	SS304	307.	300.	317.	302.	314.
73)	TENSILE_Zr.5	Nickel	331.	312.	340.	317.	339.
74)	TENSILE_41.10	F82H	308.	299.	316.	301.	314.

75) TENSILE_41.11	F82H	323.	304.	331.	309.	330.
76) CHEVRON_30.17	SS304	328.	312.	337.	318.	335.
77) CHEVRON_30.18	SS304	319.	306.	327.	311.	324.
78) TENSILE_41.12	F82H	331.	304.	342.	313.	340.
79) THERMOMETRY.9	SiC(Irr)	336.	294.	366.	306.	358.
80) THERMOMETRY.10	SiC(Irr)	335.	293.	368.	304.	358.
81) THERMOMETRY.11	SiC(Irr)	335.	292.	367.	302.	359.
82) THERMOMETRY.12	SiC(Irr)	335.	292.	366.	302.	358.
83) SUPPORT_DISK.1	Moly	309.	288.	328.	295.	327.
84) SUPPORT_DISK.2	Moly	288.	274.	294.	280.	294.
85) HOLDER.2	AL-6061	292.	283.	296.	289.	295.
87) HOLDER.3	AL-6061	286.	276.	291.	283.	290.
89) HOUSING	AL-6061	62.	56.	68.	57.	64.

PROPERTY SUMMARY AT THE AVERAGE PART TEMPERATURE

Name	Material	Thermal Cond. (W/m·ºC)	Thermal Exp. Coeff. (µm/m·°C)	Emis (---)
1) ENDCAP	AL-6061	169.333	0.00	0.050
3) GRAFOIL.1	GRAFOIL	38.000	1.00	0.500
4) GRAFOIL.2	GRAFOIL	38.000	1.00	0.500
5) GRAFOIL.3	GRAFOIL	38.000	1.00	0.500
6) HOLDER.1	AL-6061	176.000	25.36	0.057
8) ROLLPIN.1	SS304	20.488	0.00	0.143
9) TENSILE_Cu.1	Copper	380.092	0.00	0.032
10) TENSILE_Al.1	AL-6061	176.000	0.00	0.058
11) CHEVRON_Cu.1	Copper	378.858	0.00	0.032
12) CHEVRON_Cu.2	Copper	380.069	0.00	0.032
13) TENSILE_Cu.2	Copper	378.908	0.00	0.032
14) TENSILE_Al.2	AL-6061	176.000	0.00	0.057
15) TENSILE_Cu.3	Copper	379.731	0.00	0.032
16) CHEVRON_Cu.3	Copper	378.994	0.00	0.032
17) CHEVRON_Cu.4	Copper	380.150	0.00	0.032
18) TENSILE_Al.3	AL-6061	176.000	0.00	0.058
19) TENSILE_Cu.4	Copper	380.030	0.00	0.032
20) TENSILE_Al.4	AL-6061	176.000	0.00	0.058
21) CHEVRON_Cu.5	Copper	378.807	0.00	0.032
22) CHEVRON_Cu.6	Copper	380.011	0.00	0.032
23) TENSILE_Cu.5	Copper	378.839	0.00	0.032
24) TENSILE_Al.5	AL-6061	176.000	0.00	0.057
25) TENSILE_30.1	SS304	19.759	0.00	0.143
26) CHEVRON_30.1	SS304	19.899	0.00	0.143
27) CHEVRON_30.2	SS304	19.595	0.00	0.143
28) TENSILE_30.2	SS304	19.912	0.00	0.143
29) THERMOMETRY.1	SiC(Irr)	4.986	3.38	0.900
30) THERMOMETRY.2	SiC(Irr)	4.987	3.36	0.900
31) THERMOMETRY.3	SiC(Irr)	4.989	3.35	0.900
32) THERMOMETRY.4	SiC(Irr)	4.987	3.36	0.900
33) ROLLPIN.2	SS304	20.652	0.00	0.143
34) TENSILE_Ni.1	Nickel	66.362	0.00	0.185
35) TENSILE_41.1	F82H	33.751	11.34	0.143
36) CHEVRON_30.3	SS304	19.924	0.00	0.143
37) CHEVRON_30.4	SS304	19.629	0.00	0.143
38) TENSILE_Ni.2	Nickel	64.918	0.00	0.185
39) TENSILE_41.2	F82H	33.782	11.27	0.143
40) TENSILE_Ni.3	Nickel	65.359	0.00	0.185
41) CHEVRON_30.5	SS304	19.937	0.00	0.143
42) CHEVRON_30.6	SS304	19.631	0.00	0.143

```
  43) TENSILE_30.3                    SS304       19.987      0.00      0.143
  44) TENSILE_Ni.4                    Nickel      66.349      0.00      0.185
  45) TENSILE_30.4                    SS304       19.857      0.00      0.143
  46) CHEVRON_30.7                    SS304       19.932      0.00      0.143
  47) CHEVRON_30.8                    SS304       19.630      0.00      0.143
  48) TENSILE_Ni.5                    Nickel      64.820      0.00      0.185
  49) TENSILE_41.3                    F82H        33.785     11.26      0.143
  50) TENSILE_41.4                    F82H        33.753     11.33      0.143
  51) CHEVRON_30.9                    SS304       19.917      0.00      0.143
  52) CHEVRON_30.10                   SS304       19.618      0.00      0.143
  53) TENSILE_41.5                    F82H        33.734     11.38      0.143
  54) THERMOMETRY.5                   SiC(Irr)     4.985      3.39      0.900
  55) THERMOMETRY.6                   SiC(Irr)     4.985      3.39      0.900
  56) THERMOMETRY.7                   SiC(Irr)     4.984      3.39      0.900
  57) THERMOMETRY.8                   SiC(Irr)     4.984      3.39      0.900
  58) ROLLPIN.3                       SS304       20.499      0.00      0.143
  59) TENSILE_Zr.1                    Nickel      66.729      0.00      0.185
  60) TENSILE_Zr.2                    Nickel      65.835      0.00      0.185
  61) CHEVRON_30.11                   SS304       19.823      0.00      0.143
  62) CHEVRON_30.12                   SS304       19.539      0.00      0.143
  63) TENSILE_Zr.3                    Nickel      65.342      0.00      0.185
  64) TENSILE_41.6                    F82H        33.799     11.23      0.143
  65) TENSILE_41.7                    F82H        33.768     11.30      0.143
  66) CHEVRON_30.13                   SS304       19.818      0.00      0.143
  67) CHEVRON_30.14                   SS304       19.525      0.00      0.143
  68) TENSILE_41.8                    F82H        33.749     11.34      0.143
  69) TENSILE_Zr.4                    Nickel      66.832      0.00      0.185
  70) TENSILE_41.9                    F82H        33.768     11.30      0.143
  71) CHEVRON_30.15                   SS304       19.807      0.00      0.143
  72) CHEVRON_30.16                   SS304       19.521      0.00      0.143
  73) TENSILE_Zr.5                    Nickel      65.387      0.00      0.185
  74) TENSILE_41.10                   F82H        33.799     11.23      0.143
  75) TENSILE_41.11                   F82H        33.767     11.30      0.143
  76) CHEVRON_30.17                   SS304       19.807      0.00      0.143
  77) CHEVRON_30.18                   SS304       19.683      0.00      0.143
  78) TENSILE_41.12                   F82H        33.749     11.34      0.143
  79) THERMOMETRY.9                   SiC(Irr)     4.987      3.37      0.900
  80) THERMOMETRY.10                  SiC(Irr)     4.987      3.37      0.900
  81) THERMOMETRY.11                  SiC(Irr)     4.987      3.37      0.900
  82) THERMOMETRY.12                  SiC(Irr)     4.987      3.37      0.900
  83) SUPPORT_DISK.1                  Moly       126.701      0.00      0.058
  84) SUPPORT_DISK.2                  Moly       127.559      0.00      0.056
  85) HOLDER.2                        AL-6061    176.000     25.36      0.057
  87) HOLDER.3                        AL-6061    176.000     25.31      0.056
  89) HOUSING                         AL-6061    166.914     24.21      0.050

--------------------------------------------------------------------------------
CONTACT SUMMARY FOR CONTACT ID 97: HOLDER.1 To HOUSING
   Contact surface material:      AL-6061
   Target surface material:       AL-6061
   Interstitial gas:               Helium
   Effective surface roughness:     2.263 µm
   Effective asperity slope:        0.214 rad
   Effective microhardness:         1.220 GPa

                                              Average      Minimum      Maximum
                                           ------------ ------------ ------------
   ~~~~~~~~~~~ direct results ~~~~~~~~~~
   Contact status                                1.000        1.000        1.000
   Contact temperature (°C)                    291.204      283.160      294.112
   Target temperature (°C)                      63.886       60.605       67.060
   Geometric gas gap (µm)                      170.122       29.499      170.614
```

```
   Contact pressure (MPa)                     0.000        0.000        0.000
   Gap conduction heat flux (kW/m²)         323.853      304.983     3869.039
   Radiation heat flux (kW/m²)                0.000        0.000        0.000
   Contact conduction heat flux (kW/m²)       0.000        0.000        0.000
   Total heat flux (kW/m²)                  323.853      304.983     3869.039
   Thermal contact conductance (W/m²·C)    1425.923     1375.280    17223.685
   ~~~~~~~~~~ derived results ~~~~~~~~~~
   Effective gas gap (µm)                   143.465        8.878      144.503
   Contact thermal jump distance (µm)         1.531        1.513        1.537
   Target thermal jump distance (µm)          1.362        1.347        1.366
   Effective contact pressure (MPa)           0.000        0.000        0.000
   Pressure index                            13.534       13.534       13.534
   Gas thermal conductivity (W/m·°C)          0.203        0.202        0.203
   Solid spot conductance (W/m²·C)            0.000        0.000        0.000
   Gas gap conductance (W/m²·C)            1425.162     1374.668    17137.019

   Contact status codes:
    ---------------------------------------------
    0=open/no heat transfer, 1=near-field contact
    2=closed and sliding,    3=closed and sticking

------------------------------------------------------------------------------
CONTACT SUMMARY FOR CONTACT ID 99: HOLDER.2 To HOUSING
   Contact surface material:      AL-6061
   Target surface material:       AL-6061
   Interstitial gas:               Helium
   Effective surface roughness:     2.263 µm
   Effective asperity slope:        0.214 rad
   Effective microhardness:         1.220 GPa

                                            Average      Minimum      Maximum
                                        ------------ ------------ ------------
   ~~~~~~~~~~~ direct results ~~~~~~~~~~
   Contact status                             1.000        1.000        1.000
   Contact temperature (°C)                 291.226      282.788      292.976
   Target temperature (°C)                   64.313       64.099       67.222
   Geometric gas gap (µm)                   170.122       29.499      170.500
   Contact pressure (MPa)                     0.000        0.000        0.000
   Gap conduction heat flux (kW/m²)         323.203      304.545     3783.048
   Radiation heat flux (kW/m²)                0.000        0.000        0.000
   Contact conduction heat flux (kW/m²)       0.000        0.000        0.000
   Total heat flux (kW/m²)                  323.203      304.545     3783.048
   Thermal contact conductance (W/m²·C)    1426.035     1374.394    17240.680
   ~~~~~~~~~~ derived results ~~~~~~~~~~
   Effective gas gap (µm)                   143.508        8.878      144.528
   Contact thermal jump distance (µm)         1.532        1.514        1.537
   Target thermal jump distance (µm)          1.363        1.354        1.367
   Effective contact pressure (MPa)           0.000        0.000        0.000
   Pressure index                            13.534       13.534       13.534
   Gas thermal conductivity (W/m·°C)          0.203        0.202        0.203
   Solid spot conductance (W/m²·C)            0.000        0.000        0.000
   Gas gap conductance (W/m²·C)            1425.216     1373.797    17146.385

   Contact status codes:
    ---------------------------------------------
    0=open/no heat transfer, 1=near-field contact
    2=closed and sliding,    3=closed and sticking

------------------------------------------------------------------------------
CONTACT SUMMARY FOR CONTACT ID 101: HOLDER.3 To HOUSING
   Contact surface material:      AL-6061
   Target surface material:       AL-6061
```

```
Interstitial gas:               Helium
Effective surface roughness:     2.263 µm
Effective asperity slope:        0.214 rad
Effective microhardness:         1.220 GPa

                                       Average      Minimum      Maximum
                                     ------------ ------------ ------------
~~~~~~~~~~~ direct results ~~~~~~~~~~
Contact status                           1.000        1.000        1.000
Contact temperature (°C)               285.417      276.464      288.525
Target temperature (°C)                 63.441       59.977       66.914
Geometric gas gap (µm)                 170.122       29.499      170.584
Contact pressure (MPa)                   0.000        0.000        0.000
Gap conduction heat flux (kW/m²)       313.350      298.398     3718.829
Radiation heat flux (kW/m²)              0.000        0.000        0.000
Contact conduction heat flux (kW/m²)     0.000        0.000        0.000
Total heat flux (kW/m²)                313.350      298.398     3718.829
Thermal contact conductance (W/m²·C)  1412.852     1359.873    17208.822
~~~~~~~~~~ derived results ~~~~~~~~~~
Effective gas gap (µm)                 144.143        8.878      144.862
Contact thermal jump distance (µm)       1.515        1.488        1.525
Target thermal jump distance (µm)        1.350        1.329        1.358
Effective contact pressure (MPa)         0.000        0.000        0.000
Pressure index                          13.534       13.534       13.534
Gas thermal conductivity (W/m·°C)        0.202        0.200        0.203
Solid spot conductance (W/m²·C)          0.000        0.000        0.000
Gas gap conductance (W/m²·C)          1412.162     1359.398    17128.494

Contact status codes:
 ---------------------------------------------
 0=open/no heat transfer, 1=near-field contact
 2=closed and sliding,    3=closed and sticking
```

APPENDIX A2: FABRICATION REQUEST SHEETS

Capsule Fabrication Request Sheet

Page 1 of 1
Date 9/19/2019

Capsule Number: JULI01

Irradiation Conditions

Irradiation Location	HT	7
Design Temperature		300
First Cycle Goal		485
Irradiation Time	0.5	cyc.
Irradiation Charge Number		N/A
Holder diameter	9.18	mm (0.3614 in) at 20°C
Fill Gas		Helium

Approvals

	Request	Build
Performed by:	9/19/19	9/23/19
Checked by:	9/23/19	9/23/19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	AL 6061	1		20930	20930	19-01	4.2881
End Cap	X3E020977A634	C	2	AL 4047	1		20823	20850	18-70	0.6140
Spring Pin	S18-39-GEN_TEN	0	91610A207	18-8 SS	3		20971	20971	3 Total	0.3926
Wave Spring	S18-39-GEN_TEN	0	CM08-L3-S17	17-7 SS	2		20770	20770	2 Total	0.2523
Holder	S18-39-GEN_TEN	0	2	Al 6061	3	OD = 9.18	20870	20939	19-01	1.2057
									19-02	1.2036
									19-03	1.2075
Chevron	S16-18-FUSSAM01	1	1	304 SS	16	ET-145 thru ET-160	20981	20981	16 Total	1.7086
Chevron	S16-18-FUSSAM01	1	1	Cu	8	Cu-01 thru Cu-08	20982	20982	8 Total	0.9915
SSJ2 specimen	S16-18-FUSSAM01	1	3	Steel	36		20991	20991	M10S 01	0.1674
									M10S 02	0.1666
							21020	21020	M11S 08	0.1696
									M11S 09	0.1776
									M11S 10	0.1611
				Ni			21011	21011	M12N 01	0.2056
									M12N 12	0.2065
							21012	21012	M13N 10	0.195
									M13N 11	0.2021
									M13N 12	0.1951
				Al			21019	21019	M1A 01	0.0566
									M1A 02	0.0539
									M1A 03	0.0594
							21018	21018	M2A 07	0.0575
									M2A 08	0.0579
									M2A 09	0.0584
				Steel			21009	21009	M3S 01	0.1786
									M3S 02	0.1781
							21010	21010	M4S 06	0.1765
									M4S 07	0.1788
				Cu			21017	21017	M5C 01	0.2052
									M5C 02	0.202
									M5C 03	0.2021
							20983	20983	M6C 02	0.1882
									M6C 04	0.1911
									M6C 05	0.1999
				Ni			21023	21023	M7N 01	0.1842
									M7N 02	0.1729
				Steel			21021	21021	M8S 01	0.167
									M8S 02	0.172
									M8S 03	0.1678
							21022	21022	M9S08	0.1817
									M9S09	0.1643
				Grade91			20985	20985	P1X1	0.1755
									P1Z2	0.1751
									P2X3	0.1742
Thermometry	S16-18-FUSSAM01	1	7	SiC	12	081 thru 092	19759	20657	081	0.1006
									082	0.1002
									083	0.1006
									084	0.1003
									085	0.1004
									086	0.1008
									087	0.1008
									088	0.0976
									089	0.0986
									090	0.1003
									091	0.0976
									092	0.0951
									total mass	18.8823
									specimen mass	5.8255

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S18-39-GEN_TEN	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			Helium

Capsule Fabrication Request Sheet

Capsule Number: JULI02

Irradiation Conditions

Irradiation Location	HT	7
Design Temperature		300
First Cycle Goal		485
Irradiation Time	0.5	cyc.
Irradiation Charge Number		N/A
Holder diameter	9.18	mm (0.3614 in) at 20°C
Fill Gas		Helium

Approvals

	Request	Build
Performed by:	[signature] 9/19/19	[signature] 9/23/19
Checked by:	[signature] 9/23/19	[signature] 9/23/19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	AL 6061	1		20930	20930	19-02	4.2930
End Cap	X3E020977A634	C	2	AL 4047	1		20823	20850	18-72	0.6138
Spring Pin	S18-39-GEN_TEN	0	91610A207	18-8 SS	3		20971	20971	3 Total	0.3922
Wave Spring	S18-39-GEN_TEN	0	CM08-L3-S17	17-7 SS	2		20770	20770	2 Total	0.2544
Holder	S18-39-GEN_TEN	0	2	Al 6061	3	OD = 9.18	20870	20939	19-04	1.2079
									19-05	1.2056
									19-06	1.2085
Chevron	S16-18-FUSSAM01	1	1	304 SS	22	ET-161 thu ET-182	20981	20981	22 Total	2.3695
Chevron	S16-18-FUSSAM01	1	1	Cu	2	Cu-09, Cu-10	20982	20982	2 Total	0.2447
SSJ2 specimen	S16-18-FUSSAM01	1	3	OFRAC	36		20984	20984	FD-01	0.1754
									FD-02	0.1746
									FD-11	0.172
				Steel			20991	20991	M10S 03	0.1763
									M10S 04	0.1794
									M10S 05	0.1666
							21020	21020	M11S 11	0.1662
									M11S 12	0.1754
				Ni			21011	21011	M12N 03	0.2044
									M12N 04	0.2073
									M12N 05	0.1998
							21012	21012	M13N 04	0.187
									M13N 05	0.2027
				Al			21019	21019	M1A 04	0.0586
									M1A 05	0.0582
							21018	21018	M2A 10	0.0555
									M2A 11	0.0586
				Steel			21009	21009	M3S 03	0.1796
									M3S 04	0.1764
									M3S 05	0.1791
							21010	21010	M4S 08	0.1742
									M4S 09	0.1742
									M4S 10	0.1748
				Cu			21017	21017	M5C 04	0.1992
							20983	20983	M6C 01	0.1966
				Ni			21023	21023	M7N 03	0.1745
									M7N 04	0.1845
									M7N 05	0.1755
				Steel			21021	21021	M8S 04	0.1686
									M8S 05	0.1666
							21022	21022	M9S10	0.1754
									M9S11	0.1641
									M9S12	0.1734
				Grade 91			20985	20985	P2Z1	0.1777
									P3X2	0.1757
									P3Z3	0.1813
Thermometry	S16-18-FUSSAM01	1	7	SiC	12	093 thru 104	19759	20657	C93	0.1002
									C94	0.0981
									C95	0.1001
									C96	0.0974
									C97	0.1004
									C98	0.0979
									C99	0.0982
									100	0.1000
									101	0.1007
									102	0.1008
									103	0.1003
									104	0.1008
									total mass	18.9749
									specimen mass	5.9894

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S18-39-GEN_TEN	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			Helium

Capsule Fabrication Request Sheet

Date 9/19/2019

Capsule Number: JULI03

Irradiation Conditions

Irradiation Location	TRRH	6
Design Temperature		300
First Cycle Goal		485
Irradiation Time	1	cyc.
Irradiation Charge Number		N/A
Holder diameter	9.18	mm (0.3614 in) at 20°C
Fill Gas		Helium

Approvals

	Request	Build
Performed by:	[signature] 9/19/19	[signature] 9/23/19
Checked by:	[signature] 9/23/19	[signature] 9/23/19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	AL 6061	1		20930	20930	19-03	4.3022
End Cap	X3E020977A634	C	2	AL 4047	1		20823	20850	18-73	0.6159
Spring Pin	S18-39-GEN_TEN	0	91610A207	18-8 SS	3		20971	20971	3 Total	0.3911
Wave Spring	S18-39-GEN_TEN	0	CM08-L3-S17	17-7 SS	2		20770	20770	2 Total	0.2527
Holder	S18-39-GEN_TEN	0	2	Al 6061	3	OD = 9.18	20870	20939	19-07	1.2077
									19-08	1.2053
									19-09	1.2081
Chevron	S16-18-FUSSAM01	1	1	304 SS	16	ET-183 thru ET-198	20981	20981	16 Total	1.6991
Chevron	S16-18-FUSSAM01	1	1	Cu	8	Cu-11 thru Cu-18	20982	20982	8 Total	0.9964
SSJ2 specimen	S16-18-FUSSAM01	1	3	Steel	36		20991	20991	M10S 06	0.1715
									M10S 07	0.1703
							21020	21020	M11S 13	0.1776
									M11S 14	0.1716
									M11S 19	0.1689
				Ni			21011	21011	M12N 06	0.2044
									M12N 07	0.1915
							21012	21012	M13N 01	0.1892
									M13N 02	0.2003
									M13N 03	0.1874
				Al			21019	21019	M1A 06	0.0474
									M1A 07	0.0591
									M1A 16	0.0592
							21018	21018	M2A 12	0.0534
									M2A 15	0.0535
									M2A13	0.055
				Steel			21009	21009	M3S 06	0.1774
									M3S 07	0.1794
							21010	21010	M4S 11	0.1754
									M4S 12	0.1752
				Cu			21017	21017	M5C 05	0.1975
									M5C 06	0.2105
									M5C 07	0.2047
							20983	20983	M6C 03	0.1951
									M6C 07	0.2071
									M6C 08	0.205
				Ni			21023	21023	M7N 06	0.1742
									M7N 07	0.1893
				Steel			21021	21021	M8S 06	0.171
									M8S 07	0.1633
									M8S 10	0.1598
							21022	21022	M9S13	0.1738
									M9S14	0.1697
				Grade 91			20985	20985	P1K2	0.1742
									P1Z3	0.1743
									P2K1	0.1851
Thermometry	S16-18-FUSSAM01	1	7	SiC	12	106 thru 117	19759	20657	106	0.0995
									107	0.1006
									108	0.1008
									109	0.1003
									110	0.0982
									111	0.0988
									112	0.0983
									113	0.0984
									114	0.0983
									115	0.0980
									116	0.0983
									117	0.1006
									total mass	18.8929
									specimen mass	5.8243

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S18-39-GEN_TEN	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			Helium

Capsule Fabrication Request Sheet

Date 9/19/2019

Capsule Number: JULI04

Irradiation Conditions

Irradiation Location	TRRH	6
Design Temperature		300
First Cycle Goal		485
Irradiation Time	1	cyc.
Irradiation Charge Number		N/A
Holder diameter	9.18	mm (0.3614 in) at 20°C
Fill Gas		Helium

Approvals

	Request	Build
Performed by:	9/19/19	9/23/19
Checked by:	9/28/19	9/23/19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	AL 6061	1		20930	20930	19-04	4.3047
End Cap	X3E020977A634	C	2	AL 4047	1		20823	20850	18-74	0.6154
Spring Pin	S18-39-GEN_TEN	0	91610A207	18-8 SS	3		20971	20971	3 Total	0.3912
Wave Spring	S18-39-GEN_TEN	0	CM08-L3-S17	17-7 SS	2		20770	20770	2 Total	0.2535
Holder	S18-39-GEN_TEN	0	2	Al 6061	3	OD = 9.18	20870	20939	19-10	1.2066
									19-11	1.2053
									19-13	1.2074
Chevron	S16-18-FUSSAM01	1	1	304 SS	22	ET-199 thru ET-220	20981	20981	22 Total	2.3691
Chevron	S16-18-FUSSAM01	1	1	Cu	2	Cu-19, Cu-20	20982	20982	2 Total	0.2376
SSJ2 specimen	S16-18-FUSSAM01	1	3	OFRAC	36		20984	20984	FD-04	0.1757
									FD-06	0.1779
									FD-12	0.1776
				Steel			20991	20991	M1CS 09	0.1744
									M1CS 10	0.1707
									M1CS 16	0.171
							21020	21020	M11S 16	0.1768
									M11S 17	0.173
				Ni			21011	21011	M12N 08	0.2006
									M12N 09	0.2018
									M12N 10	0.2046
							21012	21012	M13N 13	0.192
									M13N 20	0.2025
				Al			21019	21019	M1A 09	0.0562
									M1A 10	0.0588
							21018	21018	M2A 16	0.0562
									M2A 17	0.0568
				Steel			21009	21009	M3S 08	0.1814
									M3S 09	0.1775
									M3S 10	0.1784
							21010	21010	M4S 13	0.1757
									M4S 14	0.1769
									M4S 15	0.1762
				Cu			21017	21017	M5C 08	0.2044
							20983	20983	M6C 09	0.2024
				Ni			21023	21023	M7N 08	0.1865
									M7N 09	0.1853
									M7N 10	0.1758
				Steel			21021	21021	M8S 12	0.1726
									M8S13	0.1633
							21022	21022	M9S06	0.1654
									M9S15	0.1712
									M9S17	0.1677
				Grade 91			20985	20985	P2Z2	0.1762
									P3X3	0.1796
									P5Z1	0.1784
Thermometry	S16-18-FUSSAM01	1	7	SiC	12	118, 119, 153, 121 thru 129	19759	20857	118	0.0984
									119	0.1007
									120	0.1012
									121	0.1001
									122	0.1005
									123	0.1008
									124	0.1008
									125	0.1003
									126	0.1002
									127	0.1006
									128	0.0999
									129	0.1000
									total mass	19.0158
									specimen mass	6.0215

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S18-39-GEN_TEN	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			Helium

Capsule Fabrication Request Sheet

Capsule Number: JULI05

Irradiation Conditions

Irradiation Location	TRRH	6
Design Temperature		300
First Cycle Goal		485
Irradiation Time	2	cyc.
Irradiation Charge Number		N/A
Holder diameter	9.18	mm (0.3614 in) at 20°C
Fill Gas		Helium

Approvals

	Request	Build
Performed by:	9/19/19	9/23/19
Checked by:	9/23/19	9/23/19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	AL 6061	1		20930	20930	19-05	4.3060
End Cap	X3E020977A634	C	2	AL 4047	1		20823	20850	18-75	0.6156
Spring Pin	S18-39-GEN_TEN	0	91610A207	18-8 SS	3		20971	20971	3 Total	0.3917
Wave Spring	S18-39-GEN_TEN	0	CM08-L3-S17	17-7 SS	2		20770	20770	2 Total	0.0269
Holder	S18-39-GEN_TEN	0	2	Al 6061	3	OD = 9.18	20870	20939	19-14	1.2077
									19-15	1.206
									19-16	1.2065
Chevron	S16-18-FUSSAM01	1	1	304 SS	16	ET-221 thru ET-236	20981	20981	16 Total	1.7018
Chevron	S16-18-FUSSAM01	1	1	Cu	8	Cu-21 thru Cu-28	20982	20982	8 Total	0.9944
SSJ2 specimen	S16-18-FUSSAM01	1	3	Steel	36		20991	20991	M10S 11	0.1748
									M10S 12	0.1715
							21020	21020	M11S 04	0.1621
									M11S 05	0.1744
									M11S 18	0.1755
				Ni			21011	21011	M12N 17	0.2078
									M12N 18	0.2031
							21012	21012	M13N 06	0.2011
									M13N 07	0.1983
									M13N 15	0.1855
				Al			21019	21019	M1A 11	0.0561
									M1A 12	0.0576
									M1A 13	0.0598
							21018	21018	M2A 01	0.0586
									M2A 02	0.0551
									M2A 03	0.0564
				Steel			21009	21009	M3S 11	0.1761
									M1A 13	0.0598
							21018	21018	M2A 01	0.0586
									M2A 02	0.0551
									M2A 03	0.0564
				Steel			21009	21009	M3S 11	0.1761
									M3S 12	0.1798
							21010	21010	M4S 01	0.1761
									M4S 02	0.175
				Cu			21017	21017	M5C 09	0.1898
									M5C 10	0.2117
									M5C 11	0.2049
							20983	20983	M6C 10	0.1999
									M6C 12	0.1846
									M6C 13	0.1977
				Ni			21023	21023	M7N 11	0.1722
									M7N 12	0.1875
				Steel			21021	21021	M8S 15	0.1652
									M8S 16	0.1712
									M8S 17	0.1701
							21022	21022	M9S18	0.1719
									M9S19	0.1773
				Grade 91			20985	20985	P1X3	0.179
									P1Z1	0.1782
									P2X2	0.1718
Thermometry	S16-18-FUSSAM01	1	7	SiC	12	105, 130 thru 133, 135 thru 141	19759	20657	130	0.0994
									131	0.0999
									132	0.1004
									133	0.0988
									105	0.1004
									135	0.0981
									136	0.0985
									137	0.0984
									138	0.1000
									139	0.0983
									140	0.0976
									141	0.0980
									total mass	18.6821
									specimen mass	5.8377

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S18-39-GEN_TEN	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			Helium

Capsule Fabrication Request Sheet

Capsule Number: JULI06

Irradiation Conditions

Irradiation Location	TRRH	6
Design Temperature		300
First Cycle Goal		485
Irradiation Time	2	cyc.
Irradiation Charge Number		N/A
Holder diameter	9.18	mm (0.3614 in) at 20°C
Fill Gas		Helium

Approvals

	Request	Build
Performed by:	9/19/19	9/23/19
Checked by:	9/23/19	9/23/19

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	C	1	AL 6061	1		20930	20930	19-06	4.2904
End Cap	X3E020977A634	C	2	AL 4047	1		20823	20850	18-76	0.6167
Spring Pin	S18-39-GEN_TEN	0	91610A207	18-8 SS	3		20971	20971	3 Total	0.3934
Wave Spring	S18-39-GEN_TEN	0	CM08-L3-S17	17-7 SS	2		20770	20770	2 Total	0.2515
Holder	S18-39-GEN_TEN	0	2	Al 6061	3	OD = 9.18	20870	20939	19-18	1.208
									19-19	1.2089
									19-20	1.2094
Chevron	S16-18-FUSSAM01	1	1	304 SS	22	ET-237 thru ET-258	20981	20981	22 Total	2.3516
Chevron	S16-18-FUSSAM01	1	1	Cu	2	Cu-29, Cu-30	20982	20982	2 Total	0.2495
SSJ2 specimen	S16-18-FUSSAM01	1	3	OFRAC	36		20984	20984	FD-03	0.1769
									FD-07	0.178
									FD-10	0.1787
				Steel			20991	20991	M10S 13	0.1775
									M10S 14	0.1779
									M10S 15	0.171
							21020	21020	M11S 06	0.1743
									M11S 07	0.1563
				Ni			21011	21011	M12N 13	0.2045
									M12N 14	0.2051
									M12N 15	0.2039
							21012	21012	M13N 08	0.2081
									M13N 09	0.1849
				Al			21019	21019	M1A 14	0.0576
									M1A 15	0.0569
							21018	21018	M2A 05	0.0588
									M2A 19	0.0591
				Steel			21009	21009	M3S 13	0.1787
									M3S 14	0.1793
									M3S 15	0.1764
							21010	21010	M4S 03	0.1754
									M4S 04	0.1744
									M4S 05	0.1738
				Cu			21017	21017	M5C 12	0.2074
							20983	20983	M6C 14	0.2009
				Ni			21023	21023	M7N 13	0.1827
									M7N 14	0.1708
									M7N 15	0.1855
				Steel			21021	21021	M8S 19	0.1683
									M8S 20	0.1642
							21022	21022	M9S20	0.1711
									M9S21	0.1682
									M9S22	0.1717
				Grade 91			20985	20985	P2Z3	0.1756
									P3X1	0.1865
									P3Z2	0.1791
Thermometry	S16-18-FUSSAM01	1	7	SiC	12	142 thru 152, 154	19759	20657	142	0.0984
									143	0.1004
									144	0.0991
									145	0.1004
									146	0.1000
									147	0.1009
									148	0.1000
									149	0.1005
									150	0.1009
									151	0.1009
									152	0.1011
									153	0.1009
									total mass	19.0024
									specimen mass	6.0195

Assembly

	Drawing	Rev.	Comment
Assembly Drawing	S18-39-GEN_TEN	0	
Welding & Cleaning	X3E020977A633	2	
Fill Gas			Helium