ORNL/SPR-2018/860

# Assembly and Delivery of Rabbit Capsules for Irradiation of Reinforced Radiation Resistant SiC-SiC Composites in the High Flux Isotope Reactor



Annabelle G. Le Coq
Kory D. Linton
Ryan C. Gallagher
Yutai Katoh


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

**July 23, 2018**


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

**ORNL/SPR-2018/860**

Materials Science and Technology Division

# Assembly and Delivery of Rabbit Capsules for Irradiation of Reinforced Radiation Resistant SiC-SiC Composites in the High Flux Isotope Reactor

Annabelle G. Le Coq
Kory D. Linton
Ryan C. Gallagher
Yutai Katoh

Date Published: July 23, 2018

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 US Department of Energy (DOE) through the Small Business Innovation Research (SBIR) program under Solicitation DE-FOA-0001164. Neutron irradiation in the High Flux Isotope Reactor (HFIR) is made possible by the Office of Basic Energy Sciences, US DOE. The report was authored by UT-Battelle under Contract No. DE-AC05-00OR22725 with the DOE. David Bryant performed most of the capsule assembly work and managed the welding and nondestructive examinations. Specimens were provided by Tori Kennard (Physical Optics Corporation, Torrance, CA).

# ABSTRACT

The development of reinforced radiation resistant composites presents a critical challenge for in-vessel component application in advanced high temperature reactors. In its pursuit of this, Physical Optics Corporation (POC) is interested in developing a silicon carbide (SiC)-based ceramic matrix composite (CMC) with improved thermal conductivity in a high neutron radiation environment. The US Department of Energy (DOE) is supporting research efforts to develop Advanced Reactor Technology. Ultimately, the results of this project will determine the viability of using SiC matrix composites in hot structures in advanced high temperature reactors. The first objective of this project is to irradiate torsion and bend bar specimens in the High Flux Isotope Reactor (HFIR) and develop an initial data set to evaluate the evolution of composite mechanical strength, dimensional changes, and thermal conductivity. This report briefly describes the irradiation experiment design concepts, summarizes the irradiation test matrix, and reports on the successful delivery of three rabbit capsules to the HFIR. Rabbits of both torsion and bend bar configurations have been assembled, welded, evaluated, and delivered to the HFIR along with a complete quality assurance fabrication package.

# 1. INTRODUCTION

The high-temperature strength, oxidation resistance, and irradiation stability of silicon carbide (SiC) are properties which have led researchers to explore SiC as a candidate material for a variety of nuclear applications [1-6]. However, in a harsh advanced reactor environment, with high neutron radiation and high temperature, SiC thermal conductivity degrades resulting in a large temperature gradient through the composite. These large temperature gradients create a complex stress state due to differential swelling and could damage SiC components [7]. Thus, mechanical testing of irradiated SiC materials is essential for irradiation effect investigations The US Department of Energy (DOE) awarded Physical Optics Corporation (POC) a grant to experimentally investigate irradiation effects in a SiC-based ceramic matrix composite (CMC), with an improved thermal conductivity. The results obtained from this irradiation testing will provide an initial data set to evaluate the evolution of the composite properties subjected to a high neutron flux.

Irradiation capsules have been designed and fabricated to allow PyC coated SiC specimens to be irradiated in the core of the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL). Post-irradiation examination of the irradiated specimens will include mechanical strength analysis, dimensional changes, and thermal conductivity evolution. This work summarizes the assembly and delivery of three rabbits containing SiC CMC specimens to the HFIR. The specimens include rectangular bend bar specimens for flexural testing and hourglass specimens for torsion testing. This report provides a brief overview of the irradiation test matrix, the capsule design concepts, and the successful delivery of all irradiation capsules to the HFIR.

# 2. EXPERIMENT DESIGNS AND TEST MATRIX

## 2.1 BEND BAR CAPSULE DESIGN

The bend bar irradiation capsule design is shown in Figure 1. This design places three bend bar specimens in a V-4Cr-4Ti holder at the center of the rabbit housing. The specimens are surrounded by chemical vapor deposited (CVD) SiC blocks, Inconel springs, and SiC liners, to maintain the specimens in place, allow them to swell under irradiation, and prevent their contact with the holder. Two silicon carbide passive temperature monitors are placed on the outside of the CVD SiC blocks for post irradiation dilatometry. The holder is positioned in an aluminum housing, which is directly cooled by the reactor primary coolant. The nominal bend bar temperatures were determined to be around 650°C by scaling the gamma heating rate of a previously demonstrated design, meant for 800°C with respect to a new position in the HFIR. The temperature will be validated using the SiC temperature monitors.

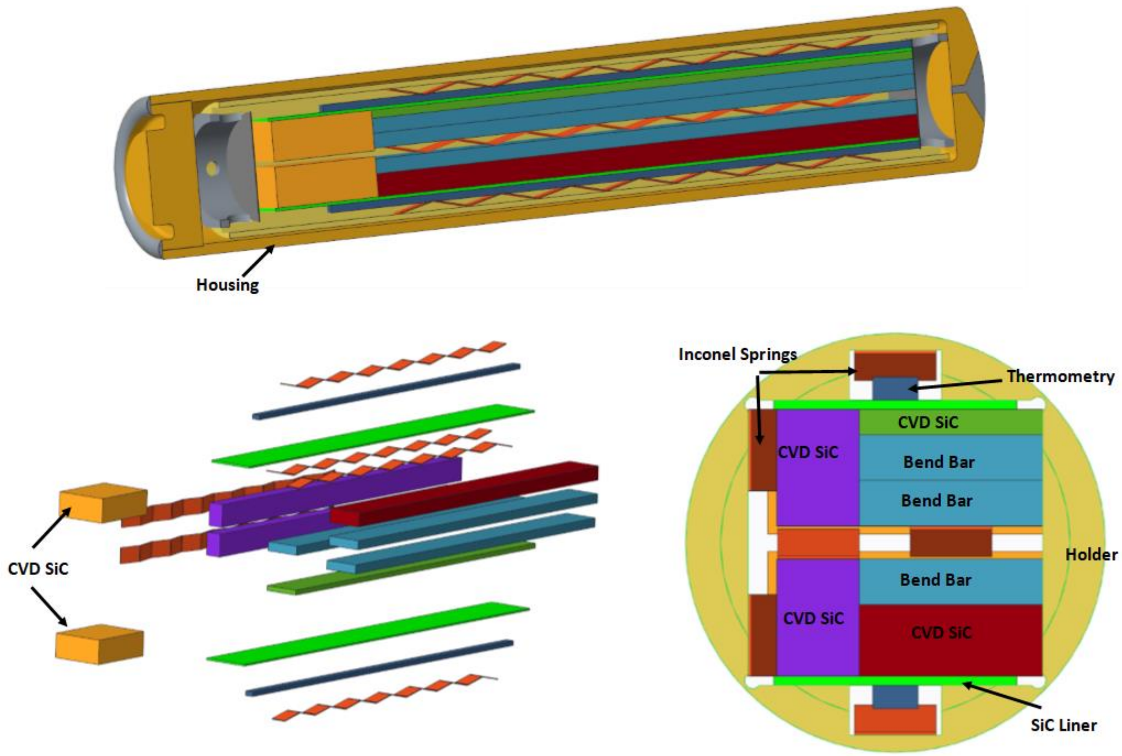


**Figure 1. Capsule design concept for irradiating SiC matrix composite bend bars specimens.**

## 2.2 TORSION CAPSULE DESIGN

Figure 2 shows the concept for the torsion rabbit design. Two rows of eight hourglass specimens stacked in the vertical direction are set inside a molybdenum holder. A center spacer separates the two rows of specimens while two retainer springs maintain the specimens centered in their holder. Molybdenum wires are used to secure the specimen stack within the holder. Two silicon carbide passive temperature monitors are placed on the outside of the CVD SiC blocks for post irradiation dilatometry. Grafoil insulator disks as well as quartz wool are placed at the top and bottom of the housing assembly reduce axial heat losses from the top and bottom hourglass specimens to the cooler surface of the capsule housing. The design was based on, and nearly identical to, a previous irradiation experiment. Finite element modeling of the previous design predicts 800°C average specimen temperatures. The thermal performance will be validated by the SiC temperature monitors, post-irradiation. Figure 3 displays the temperature contour plot for the torsional specimens.

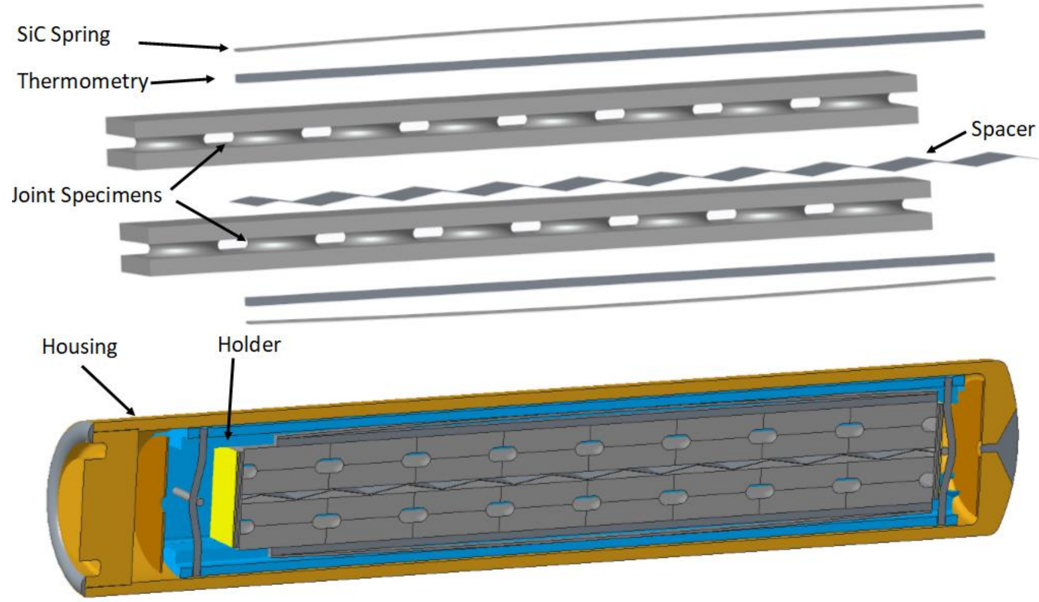


**Figure 2. Capsule design concept for irradiating SiC matrix composite hourglass specimens.**

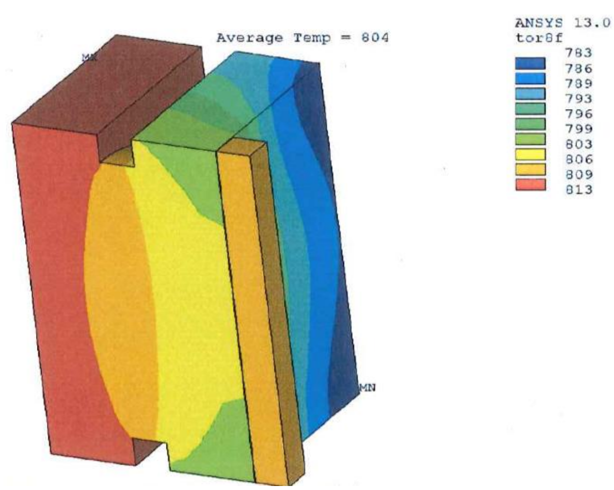


**Figure 3. SiC matrix composite hourglass specimen temperature (°C) contours during irradiation.**

## 2.3 IRRADIATION TEST MATRIX

Table 1 summarizes the irradiation test matrix. The specimens have been manufactured by POC. Each specimen was coated with PyC. Table 1 shows the loading of specimens in each rabbit along with the irradiation positions and fill gases. Each bend bar rabbit contains three bend bars while the torsion rabbit contains sixteen specimens. One bend bar rabbit will be irradiated for one cycle (cycle 481) in the HFIR, which will result in a radiation dose of approximately 1.85 dpa. The other bend bar rabbit and the torsion rabbit will be irradiated for two cycles (cycles 481 and 482) in the HFIR, which will result in a radiation dose of approximately 3.7 dpa. The targeted specimen surface temperature is approximately 650°C for the bend bars and 800°C for the joint specimens. Temperature gradients through the thickness depend on the heat flux and the specimen thermal conductivity, which varies with specimen type and neutron fluence. The nominal bend bar specimen dimensions are 42 mm length, 4 mm width, and 1 mm thickness; the nominal hourglass specimen dimensions are 6 mm × 6 mm square section and 2.8 mm height.

**Table 1. Rabbit irradiation test matrix showing the loading of specimens within each rabbit, the irradiation positions, and fill gases**

| Rabbit | Number of irradiation cycles | Specimens | Irradiation position | Fill gas |
|---|---|---|---|---|
| DCM01 | 1 | 1BB1, 1BB3, 2BB7 | TH-6 | Ne* |
| DCM02 | 2 | 1BB2, 1BB6, 2BB9 | TH-6 | Ne* |
| DCM03 | 2 | 6B01, 6B02, 6B03, 6B04, 6B05, 6B06, 6B07, 6B08, 6C01, 6C02, 6C03, 6D01, 6D02, 6D04, 6D05, 6D06 | PTP-2 | Ar |

* Or Ne equivalent

# 3. RABBIT CAPSULE ASSEMBLY AND DELIVERY TO THE HFIR

## 3.1 BEND BAR RABBITS ASSEMBLY

The two bend bar rabbits (DCM01 and DCM02) were assembled. Pictures of the complete parts layout and the parts in the holder sub-assembly for rabbit DCM01 are shown in Figure 4. Figure 5 shows the parts layout for rabbit DCM02. The signed capsule fabrication request forms are provided in APPENDIX A. Figure 6 shows a top-down view of SiC matrix composite bend bar specimens assembled inside the rabbit housing, with liners, springs and thermometry.

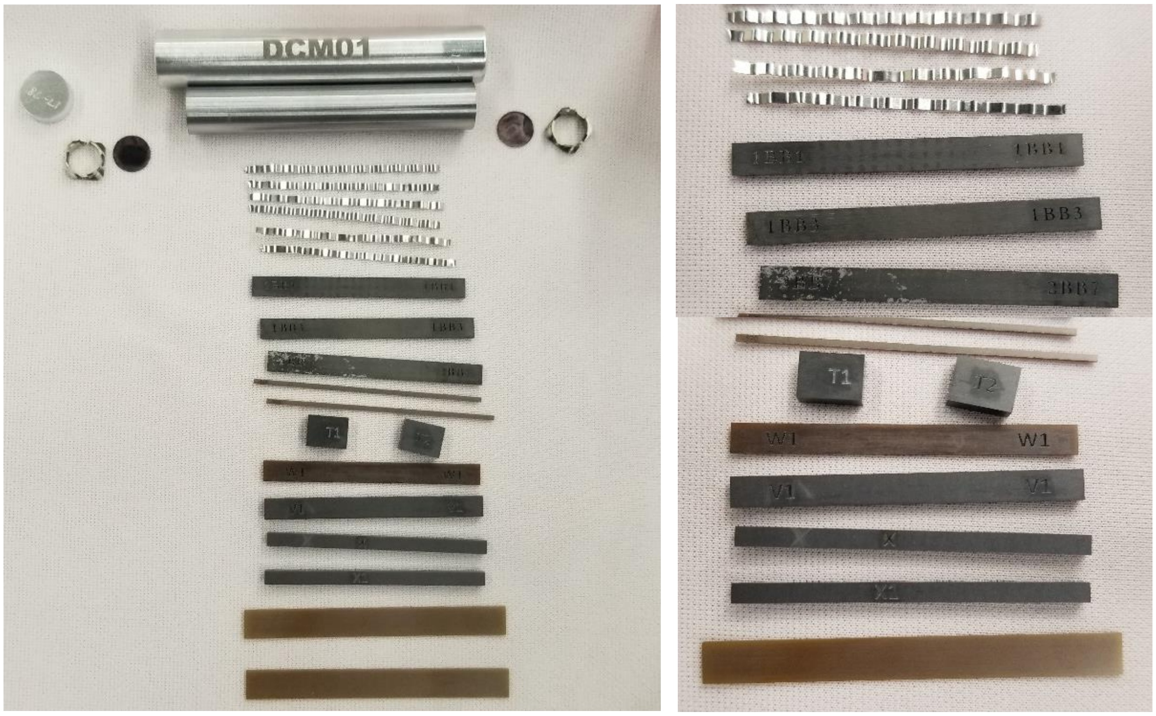


**Figure 4. Parts (left) and sub-assembly components (right) of rabbit DCM01.**

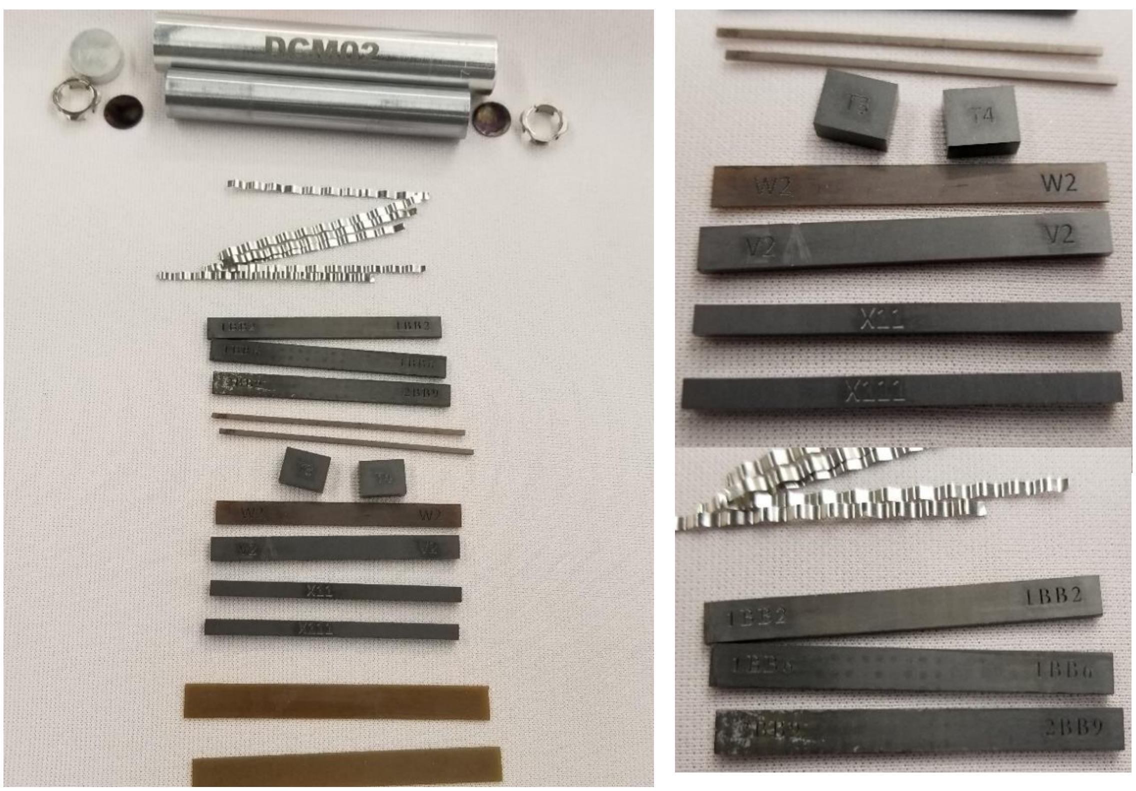


**Figure 5. Parts (left) and sub-assembly components (right) of rabbits DCM02.**

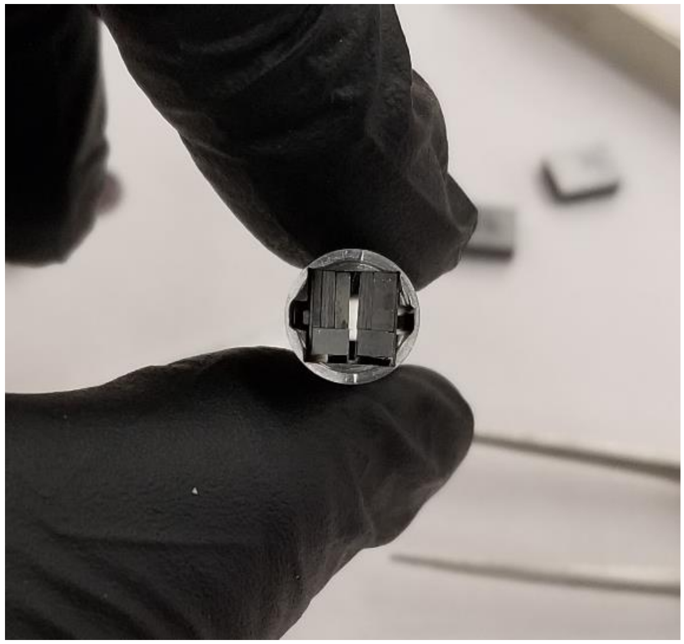

**Figure 6. Top-down view of bend bar specimens assembled inside rabbit housing DCM01.**

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 with an 59.5% Ar–He balance mixture gas three times to ensure a pure environment. The chambers were placed inside a glove box, which was also evacuated and backfilled with 59.5% Ar–He balance mixture gas. 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.

## 3.2 TORSION RABBIT ASSEMBLY

One torsion rabbit (DCM03) was assembled. A picture of the layout before irradiation is shown for this rabbit in Figure 7. The torsion rabbit and rabbit components were inspected, cleaned, assembled, and tested using the same processes and procedures as the bend bar rabbits, except that the backfill gas was pure argon instead of an 59.5% Ar–He balance mixture. All rabbits passed weld examination, leak testing, and hydrostatic compression.

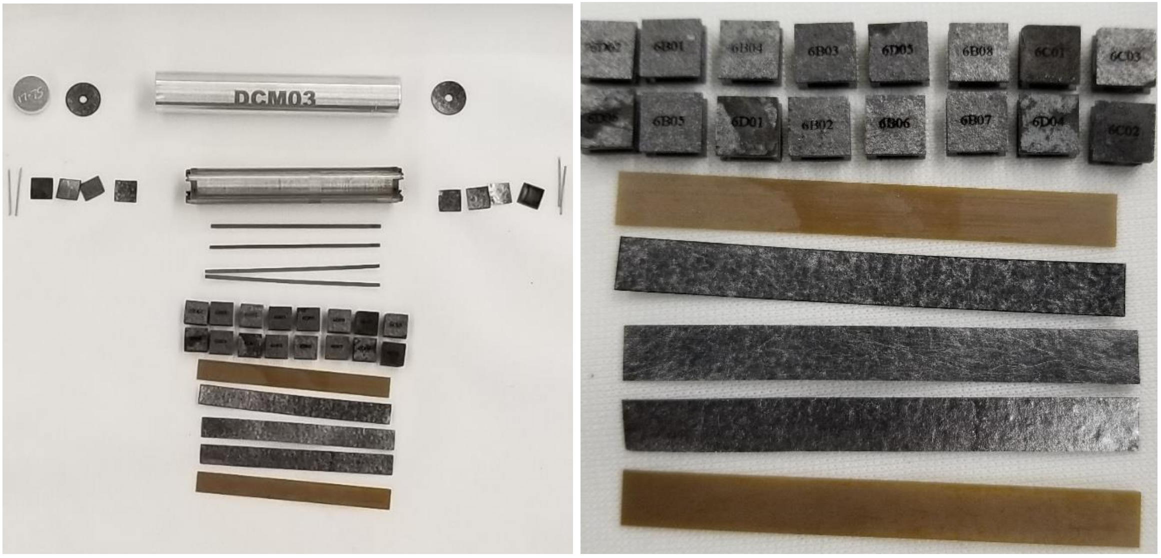


**Figure 7. Capsule parts for torsion rabbit DCM03 (left), and the joint specimens with liners and spacers (right).**

## 3.3 QUALITY ASSURANCE, FABRICATION PACKAGE, AND DELIVERY TO THE HFIR

Each rabbit irradiation experiment requires a fabrication package that is reviewed by an independent design engineer, a lead quality assurance (QA) representative, and a HFIR QA representative before acceptance for insertion into the HFIR. The fabrication package must satisfy the requirements of the Experiment Authorization Basis Document (EABD). Rabbit capsules fall under document EABD-HFIR-2009-004. This document specifies a number of requirements that the rabbits must satisfy in the areas of

- thermal safety analyses,
- material certification,
- dimensional inspection,
- cleaning,
- assembly procedure,
- sample loading,
- fill gas,
- welding, and
- nondestructive evaluation.

A unique fabrication package was prepared for the bend bar and torsion rabbit capsules. This package was reviewed and approved by an independent design engineer, lead QA representative, and HFIR QA representative and accepted by HFIR on July 12, 2018. The final signed acceptance page of the EABD is provided in APPENDIX A. All three rabbits are scheduled for insertion during HFIR cycle 481 (July 2018).

# 4. SUMMARY AND CONCLUSIONS

This work summarizes the capsule design concepts and the irradiation test matrix for three rabbit capsules, which were successfully assembled and delivered to the HFIR for insertion during cycle 481 (July 2018). Each bend bar rabbit contains three SiC matrix composite bend bars; the torsion rabbit contains sixteen SiC matrix composite hourglass specimens. The specimens will be evaluated post-irradiation to investigate the effects of irradiation on the composite mechanical strength, dimensional changes, and thermal conductivity. The rabbits were successfully assembled, welded, evaluated, and delivered to the HFIR along with a complete QA fabrication package. Pictures of the rabbit assembly process are included in this report. Documentation of the capsule fabrication and final acceptance by HFIR is provided in an appendix. Ultimately, the results of this project will determine the viability of using silicon carbide matrix composites in hot structures in advanced high temperature reactors.

## 5. WORKS CITED


1. Snead, L.L., et al., "Silicon carbide composites as fusion power reactor structural materials," *Journal of Nuclear Materials*, **417** (2011) p. 330-339.
2. Giancarli, L., et al., "Progress in blanket designs using SiCf/SiC composites," *Fusion Engineering and Design*, **61–62** (2002) p. 307-318.
3. Katoh, Y., et al., "Radiation effects in SiC for nuclear structural applications," *Current Opinion in Solid State and Materials Science*, **16** (2012) p. 143-152.
4. Katoh, Y., et al., "Current status and recent research achievements in SiC/SiC composites," *Journal of Nuclear Materials*, **455** (2014) p. 387-397.
5. Katoh, Y., et al., "Continuous SiC fiber, CVI SiC matrix composites for nuclear applications: Properties and irradiation effects," *Journal of Nuclear Materials*, **448** (2014) p. 448-476.
6. Koyanagi, T., et al., "Effects of neutron irradiation on mechanical properties of silicon carbide composites fabricated by nano-infiltration and transient eutectic-phase process," *Journal of Nuclear Materials*, **448** (2014) p. 478-486.
7. Koyanagi, Takaaki, Sosuke Kondo, and Tatsuya Hinoki. "Effect of differential swelling between fiber and matrix on the strength of irradiated SiC/SiC composites." Journal of Nuclear Materials **442.1-3** (2013): S380-S383.

# APPENDIX A. FABRICATION AND QUALITY ASSURANCE DOCUMENTATION FOR COMPLETED RABBITS

# APPENDIX A. FABRICATION AND QUALITY ASSURANCE DOCUMENTATION FOR COMPLETED RABBITS

## Capsule Fabrication Request Sheet


Date 5/8/2018

**Capsule Number:** DCM01

**Irradiation Conditions**

| | |
|---|---|
| Irradiation Location | TH 6 |
| First Cycle Goal | 480 |
| Irradiation Time | 1.0 cycles |
| Irradiation Temperature | 650 °C |
| Housing Fill Gas | 59.5Ar/He |

**Approvals**

| | Request | Build |
|---|---|---|
| Performed by: | 5/8/2018 | 5/8/18 |
| Checked by: | 5/8/18 | 5/2/2018 |

**Capsule Fabrication**

| | Drawing | Rev. | Part | Material | Count | Comment | MAT IR | FAB IR | ID | Mass (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| Housing | X3E020977A634 | A | 1 | AL 6061 | 1 | | 20713 | 20713 | 17-111 | 4.3206 |
| End Cap | X3E020977A634 | A | 2 | AL 4047 | 1 | | 20714 | 20714 | 17-78 | 0.5158 |
| KAPL Bend Bar Holder | X3E020977A325 | 0 | 6 | V-4Cr4Ti | 1 | | 18790 | 20795 | 1-15-05-04 | 7.1020 |
| Centering Thimble | X3E020977A540 | 0 | 1 | 304 SS | 2 | 51, 52 | 19583 | 19583 | 2 Total | 0.4200 |
| KAPL Bend Bar Spring | X3E020977A325 | 0 | 8 | Inconel | 6 | | 20796 | 20796 | 6 Total | 0.2480 |
| Bend Bar Specimen | S18-11-BENDBAR | 0 | 1 | SiC | 3 | | 20797 | 20797 | 1BB1 | 0.51677 |
| | | | | | | | | | 1BB3 | 0.50962 |
| | | | | | | | | | 2BB7 | 0.50270 |
| Passive Thermometry | X3E020977A325 | 0 | 10 | SiC | 2 | | 19502 | 20798 | 329 | 0.0660 |
| | | | | | | | | | 390 | 0.0670 |
| Specimen | S18-11-BENDBAR | 0 | 5 | SiC | 2 | 7.8 x 6 x 2.72 | 20863 | 20867 | T1 | 0.4070 |
| | | | | | | | | | T2 | 0.4060 |
| Specimen | S18-11-BENDBAR | 0 | 3 | SiC | 1 | 42 x 4 x 0.55 | 20863 | 20865 | W1 | 0.2740 |
| Specimen | S18-11-BENDBAR | 0 | 4 | SiC | 1 | 42 x 4 x 1.56 | 20863 | 20866 | V1 | 0.8380 |
| Specimen | S18-11-BENDBAR | 0 | 2 | SiC | 2 | 42 x 2.55 x 1.8 | 20863 | 20864 | X | 0.6220 |
| | | | | | | | | | X1 | 0.6220 |
| Liner | S12-13-MC02 | 0 | 1 | SiC | 2 | 3A, 4A | 19502 | 20028 | 2 Total | 0.3170 |
| Quartz Wool | S18-10-BENDBAR | 0 | 3 | SiO2 | | As Needed | 20679 | 20679 | | 0.0320 |
| Support disk | S18-10-BENDBAR | 0 | 2 | Moly | 2 | | 19593 | 19593 | 2 Total | 0.0640 |
| | | | | | | | | | Total Mass | 17.8505 |
| | | | | | | | | | Specimen Mass | 4.6981 |
| | | | | | | | | | Internal Mass | 13.0141 |

**Assembly**

| | Drawing | Rev. | Comment |
|---|---|---|---|
| Assembly Drawing | S18-10-BENDBAR | 0 | |
| Welding & Cleaning | X3E020977A633 | 0 | |
| Fill Gas | 59.5% Argon/Bal He | | |

## Capsule Fabrication Request Sheet



**Capsule Number:** DCM02

### Irradiation Conditions

| | |
|---|---|
| Irradiation Location | TH 6 |
| First Cycle Goal | 480 |
| Irradiation Time | 2.0 cycles |
| Irradiation Temperature | 650 °C |
| Housing Fill Gas | 59.5Ar/He |

### Approvals

| | Request | Build |
|---|---|---|
| Performed by: | 5/8/2018 | 5/8/18 |
| Checked by: | 5/8/18 | 5/2/2018 |

### Capsule Fabrication

| | Drawing | Rev. | Part | Material | Count | Comment | MAT IR | FAB IR | ID | Mass (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| Housing | X3E020977A634 | A | 1 | AL 6061 | 1 | | 20713 | 20713 | 17-116 | 4.3123 |
| End Cap | X3E020977A634 | A | 2 | AL 4047 | 1 | | 20714 | 20714 | 17-79 | 0.5154 |
| KAPL Bend Bar Holder | X3E020977A325 | 0 | 6 | V-4Cr4Ti | 1 | | 18790 | 20795 | 1-15-05-09 | 7.1020 |
| Centering Thimble | X3E020977A540 | 0 | 1 | 304 SS | 2 | 51, 52 | 19583 | 19583 | 2 Total | 0.4200 |
| KAPL Bend Bar Spring | X3E020977A325 | 0 | 8 | Inconel | 6 | | 20796 | 20796 | 6 Total | 0.2480 |
| Bend Bar Specimen | S18-11-BENDBAR | 0 | 1 | SiC | 3 | | 20797 | 20797 | 1BB2 | 0.51420 |
| | | | | | | | | | 1BB6 | 0.51850 |
| | | | | | | | | | 2BB9 | 0.49570 |
| Passive Thermometry | X3E020977A325 | 0 | 10 | SiC | 2 | | 19502 | 20798 | 308 | 0.0660 |
| | | | | | | | | | 377 | 0.0670 |
| Specimen | S18-11-BENDBAR | 0 | 5 | SiC | 2 | 7.8 x 6 x 2.72 | 20863 | 20867 | T3 | 0.4070 |
| | | | | | | | | | T4 | 0.4060 |
| Specimen | S18-11-BENDBAR | 0 | 3 | SiC | 1 | 42 x 4 x 0.55 | 20863 | 20865 | W2 | 0.2740 |
| Specimen | S18-11-BENDBAR | 0 | 4 | SiC | 1 | 42 x 4 x 1.56 | 20863 | 20866 | V2 | 0.8380 |
| Specimen | S18-11-BENDBAR | 0 | 2 | SiC | 2 | 42 x 2.55 x 1.8 | 20863 | 20864 | X11 | 0.6220 |
| | | | | | | | | | X111 | 0.6220 |
| Liner | S12-13-MC02 | 0 | 1 | SiC | 2 | 3A, 4A | 19502 | 20028 | 2 Total | 0.3170 |
| Quartz Wool | S18-10-BENDBAR | 0 | 3 | SiO2 | | As Needed | 20679 | 20679 | | 0.0320 |
| Support disk | S18-10-BENDBAR | 0 | 2 | Moly | 2 | | 19593 | 19593 | 2 Total | 0.0640 |
| | | | | | | | | | Total Mass | 17.8411 |
| | | | | | | | | | Specimen Mass | 4.6974 |
| | | | | | | | | | Internal Mass | 13.0134 |

### Assembly

| | Drawing | Rev. | Comment |
|---|---|---|---|
| Assembly Drawing | S18-10-BENDBAR | 0 | |
| Welding & Cleaning | X3E020977A633 | 0 | |
| Fill Gas | 59.5% Argon/Bal He | | |

# Capsule Fabrication Request Sheet


Date 5/10/2018

**Capsule Number:** DCM03

**Irradiation Conditions**

| | | |
|---|---|---|
| Irradiation Location | PTP | 2 |
| First Cycle Goal | | 480 |
| Irradiation Time | | 2.0 cycles |
| Irradiation Temperature | | 800 °C |
| Housing Fill Gas | | Argon |

**Approvals**

| | Request | Build |
|---|---|---|
| Performed by: | [signature] 5/8/2018 | [signature] 5/10/18 |
| Checked by: | [signature] 5/10/18 | [signature] 5/2/2018 |

**Capsule Fabrication**

| | Drawing | Rev. | Part | Material | Count | Comment | MAT IR | FAB IR | ID | Mass (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| Housing | X3E020977A634 | A | 1 | AL 6061 | 1 | | 20713 | 20713 | 17-117 | 4.3001 |
| End Cap | X3E020977A634 | A | 2 | AL 4047 | 1 | | 20714 | 20714 | 17-75 | 0.5135 |
| Specimen Holder | S13-22-TOR03 | 2 | 2 | Moly | 1 | | 20026 | 20234 | M1003 | 14.8810 |
| Holder Support Wire | S13-22-TOR03 | 2 | 3 | Moly | 4 | | 19600 | 19600 | 4 Total | 0.1040 |
| Specimen Support Foil | S13-22-TOR03 | 2 | 4 | Moly | 2 | | 19593 | 19593 | 2 Total | 0.0510 |
| Small Thermometry | X3E020977A540 | 1 | 3 | SiC | 2 | 339,391 | 19502 | 19709 | 2 Total | 0.1330 |
| Retainer Spring | S13-21-TOR02 | 0 | 2 | SiC | 2 | | 20236 | 20236 | 2 Total | 0.0450 |
| Center Spacer | S13-22-TOR03 | 2 | 7 | grafoil | 3 | | 19812 | 19812 | 3 Total | 0.1100 |
| Joint Specimen | S13-22-TOR03 | 2 | 5 | SiC | 16 | | 20797 | 20822 | 6B01 | 0.187 |
| | | | | | | | | | 6B02 | 0.181 |
| | | | | | | | | | 6B03 | 0.185 |
| | | | | | | | | | 6B04 | 0.176 |
| | | | | | | | | | 6B05 | 0.192 |
| | | | | | | | | | 6B06 | 0.186 |
| | | | | | | | | | 6B07 | 0.186 |
| | | | | | | | | | 6B08 | 0.188 |
| | | | | | | | | | 6C01 | 0.172 |
| | | | | | | | | | 6C02 | 0.175 |
| | | | | | | | | | 6C03 | 0.179 |
| | | | | | | | | | 6D01 | 0.179 |
| | | | | | | | | | 6D02 | 0.172 |
| | | | | | | | | | 6D04 | 0.171 |
| | | | | | | | | | 6D05 | 0.174 |
| | | | | | | | | | 6D06 | 0.178 |
| Insulator Disk | S13-22-TOR03 | 2 | 9 | grafoil | 8 | | 19812 | 19812 | 8 Total | 0.0450 |
| Liner | S12-13-MC02 | 0 | 1 | SiC | | Parts 1A & 2A | 19502 | 20028 | 2 Total | 0.3140 |
| Quartz Wool | S13-22-TOR03 | 2 | 6 | SiO2 | | As Needed | 20679 | 20679 | | 0.0310 |
| | | | | | | | | | Total Mass | 23.4086 |
| | | | | | | | | | Specimen Mass | 2.8810 |
| | | | | | | | | | Internal Mass | 18.5950 |

**Assembly**

| | Drawing | Rev. | omment |
|---|---|---|---|
| Assembly Drawing | S13-22-TOR03 | 2 | |
| Welding & Cleaning | X3E020977A633 | 0 | |
| Fill Gas | Argon | | |

## Section 6: Acceptance for Use of As-Built Experiment Capsule

Note: This section is used to document acceptance of the as-built experiment for reactor installation and irradiation. This section is completed **after** completion of Section 2. See notes for explanation of signatures.

1. List Applicable Rabbit Identification and Heat Generation Classification (High or Low)

| User I.D. | HFIR I.D.* | Heat Classification |
|---|---|---|
| DCM01 | DCM01 | low |
| DCM02 | DCM02 | low |
| DCM03 | DCM03 | high |

* Quality Assurance to verify correlation of User ID and HFIR ID noted above are consistent with markings presented on product body.

Independent Verification of User I.D. and HFIR I.D.: [signature] 7/10/18

2. Attach Capsule Fabrication Request Sheet or Equivalent: [signature] Lead Experimenter

3. Approvals (see notes for explanation of signature responsibilities)

| | | |
|---|---|---|
| Ryan Gallagher<br>Lead Experimenter | [signature]<br>Lead Experimenter (signature) | 7/5/18<br>Date |
| Mark C. Vance<br>Lead QA | [signature]<br>Lead QA (signature) | 7/9/18<br>Date |
| Brian L Wingfield<br>RRD QA | [signature]<br>RRD QA (signature) | 7/10/18<br>Date |
| Greg Hirtz<br>RRD EA&C Staff | [signature]<br>RRD EA&C Staff (signature) | 7/10/18<br>Date |
| N.A. No NCS Requirements<br>RRD Criticality Safety Officer | N.A. No NCS Requirements<br>RRD Criticality Safety Officer (signature) | NA<br>Date |
| N.A. No MBA Requirements<br>HFIR MBA Representative | N.A. No MBA Requirements<br>HFIR MBA Representative (signature) | NA<br>Date |
| FULLER, BRIAN E<br>HFIR Operations (print name) | [signature]<br>HFIR Operations (signature) | 07/12/2018<br>Date |