ORNL/SPR-2018/876

Assembly of Rabbit Capsules for Irradiation of Pyrolytic Carbon / Silicon Carbide Diffusion Couples in the High Flux Isotope Reactor

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June 28, 2018

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

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Materials Science and Technology Division

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Date Published: June 28, 2018

NSUF Work Package #: UF-18OR020708
Work Package Manager: Kory Linton
Milestone #: M3UF-18OR0207081

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

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ACKNOWLEDGMENTS

This research was sponsored by the Nuclear Science User Facilities (NSUF) Program of the US Department of Energy (DOE), Office of Nuclear Energy. 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 US Department of Energy. The contributions of David Bryant who assembled the capsules are gratefully acknowledged.

ACRONYMS

CVD	Chemical vapor deposition
DOE	Department of Energy
HFIR	High Flux Isotope Reactor
IPyC	Inner pyrolytic carbon
LWR	Light water reactor
MIBL	Michigan Ion Beam Laboratory
NSUF	Nuclear Science User Facilities
OPyC	Outer pyrolytic carbon
ORNL	Oak Ridge National Laboratory
PyC	Pyrocarbon
SiC	Silicon carbide
TRISO	Tristructural-isotropic

ABSTRACT

Tristructural-isotropic (TRISO)–coated particle fuel is a promising advanced fuel concept being considered for several advanced reactor applications and for accident-tolerant fuel for light water reactors. One of the aspects studied in the development of this advanced fuel concept is the release of specific fission products (Ag, Eu, and Sr). The silicon carbide (SiC) layer of TRISO fuel serves as the primary barrier to metallic fission products and actinides not retained in the fuel kernel. The goal of this project is to evaluate the effect of irradiation on the diffusion of these fission products in the SiC layer of the fuel. For this purpose, rabbit capsules containing small slab diffusion couple specimens have been assembled to be irradiated in the High Flux Isotope Reactor (HFIR). The diffusion couple specimens have been fabricated using similar processes and equipment as those used to make TRISO particles; the desired fission products have been implanted in the specimens using an ion accelerator. Moreover, the effect of temperature on the fission products diffusion will be studied separately by performing thermal experiments in the absence of irradiation. This report describes the irradiation experiment design concept, summarizes the irradiation test matrix, and reports on the successful assembly of two rabbit capsules that will be irradiated in the HFIR.

1. INTRODUCTION

Tristructural-isotropic (TRISO)–coated particle fuel is a promising advanced fuel concept being considered for several advanced reactor applications and for accident-tolerant fuel for light water reactors. This type of fuel consists of a spherical uranium-bearing fuel kernel, surrounded by a buffer layer, and successive layers of dense inner pyrolytic carbon (IPyC), silicon carbide (SiC), and dense outer pyrolytic carbon (OPyC). During operation, the SiC layer serves as the primary barrier to metallic fission products and actinides not retained in the kernel. The development of this advanced fuel concept requires a thorough understanding of fission product diffusion kinetics in the various coating layers. Previous observations suggest that irradiation influences diffusion of fission product species in SiC [1-3].

Irradiation capsules have been designed to allow the irradiation of representative specimens in the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL). Post-irradiation examination will provide diffusion depth profile data. Representative TRISO layer properties are pursued to investigate materials relevant to TRISO-coated particle fuel performance. The samples are comprised of only the pyrocarbon (PyC) and SiC layers, no fissile material is present. The diffusing fission product species of interest have been directly implanted into the specimens. A slab geometry has been pursued to simplify the post-irradiation depth profiling of the diffusion couple systems. This report summarizes the capsule design, the irradiation test matrix, and the successful assembly of the capsules for irradiation in the HFIR.

2. EXPERIMENTAL DESIGN AND TEST MATRIX

2.1 CAPSULE DESIGN

The irradiation capsule design is shown in Figure 1. This design places up to 40 diffusion couple specimens (maximum dimensions 3.35 mm x 5.55 mm x 0.30 mm) inside small cutouts in a graphite container. The container is then placed inside a square cutout in a cylindrical holder made from Nb-1Zr alloy. Passive SiC temperature monitors line the inside of the holder cutout and SiC retainer springs keep the graphite container pressed into one corner of the cutout. The holder is positioned in an aluminum housing, which is directly cooled by the reactor primary coolant. Inside the housing, centering thimbles placed at each end maintain the holder centered in the housing and keep a constant gas gap between the two components. Support disks (not shown in the figure) made from molybdenum are placed between the holder and the centering thimbles. Wires are inserted through the thimbles and the radial holes in the holder to ensure that the thimbles cannot dislodge from the holder. The small raised features above and below the base of the centering thimble (see Figure 1) reduce the contact area between the centering thimble and the contacting components (the holder and the bottom of the housing). These features significantly reduce axial heat losses through the thimbles. Grafoil insulator disks are also stacked on both ends of the capsule to further reduce axial heat losses. Quartz wool (not shown) is packed into the ends of the cutouts in the graphite container to keep the specimens in place. Finally, an end cap is welded to the housing to seal the rabbit capsule.

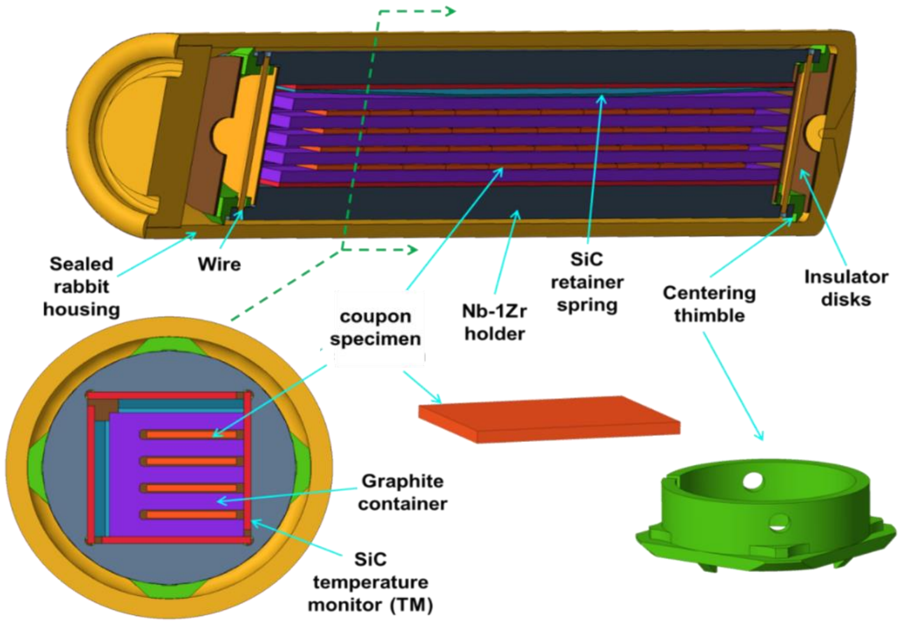

Figure 1. Section view showing irradiation capsule design concept.

Finite element modeling of this design predicts 1,100 °C average specimen temperatures [4]. The thermal performance will be validated by the SiC temperature monitors, post-irradiation. Figure 2 displays the temperature contour plot of the internal rabbit components, the specimens and the temperature monitors.

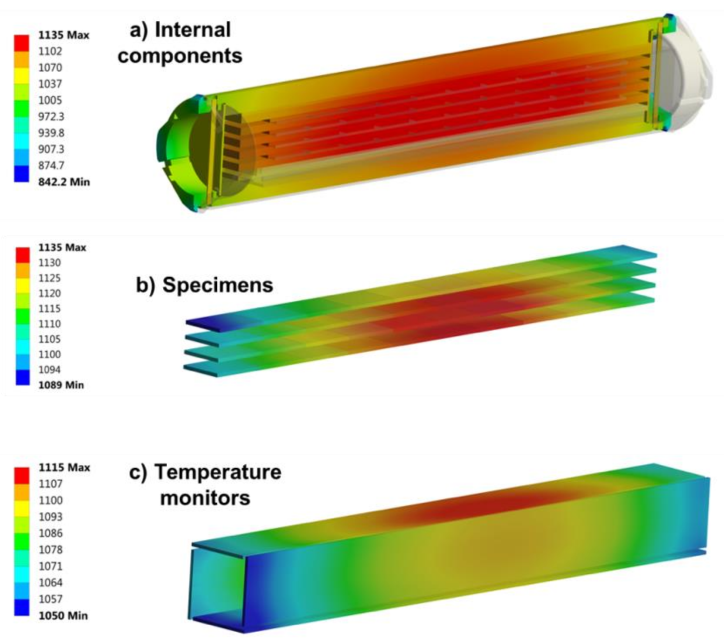

Figure 2. Predicted temperature contours showing (a) a section view of the internal components, (b) the specimens, and (c) the SiC temperature monitors.

2.2 TEST MATRIX

Table 1 summarizes the four different types of specimens that have been fabricated at ORNL. Two different types of SiC (single crystal 4H-SiC and commercially available chemical vapor deposition (CVD) SiC) have been implanted with Ag on one surface, and seal coated with SiC. In addition, layered PyC and SiC diffusion couple specimens were produced to mimic the TRISO layers in a TRISO fuel particle. Two variants of PyC/SiC/PyC specimens, SiC variant and baseline variant, were fabricated and slightly differ by their layers properties. One PyC layer was implanted with species of interest, and the PyC/SiC/PyC specimens were seal coated with SiC. The fission product species have been implanted at the Michigan Ion Beam Laboratory (MIBL). Finally, PyC/SiC/PyC specimens without any species implantation or seal coating were fabricated. Figure 3 shows an example of some fabricated specimens.

Table 1. Specimen types included in the irradiation test matrix

Specimen type	Specimen condition	Implanted species	Specimen ID*
Seal-Coated 4H-SiC	4H-SiC	Ag	4H-x 4-xx
Seal-Coated CVD-SiC	CVD-SiC	Ag	CVD-x
Seal-Coated PyC/SiC/PyC	SiC variant	Ag Eu Sr	32-xx 28-xx 35-xx
	Baseline	Ag Ag+Pd Eu Sr	30-xx Ag-xx 33-xx 34-xx
As-fabricated PyC/SiC/PyC	Blank-PyC/SiC	-	37-xx

* with -x or -xx, the specimen ID number

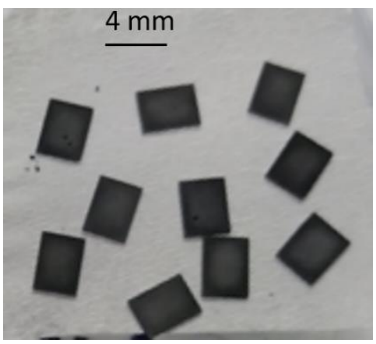

Figure 3. Example of fabricated specimens.

For each specimen type, condition and implanted species, between one and five specimens were inserted in each capsule. Table 2 summarizes the irradiation test matrix with the loading of specimens in each rabbit, the irradiation positions, and fill gases. The rabbits DC01 and DC02 contain twenty-nine and thirty specimens, respectively. The rabbits will be inserted in the hydraulic tube of the HFIR during cycle 481 (July 2018): one rabbit will be irradiated for about 5 days, which will result in a radiation dose of approximately 0.5 dpa; the other rabbit will be irradiated for about 11 days, which will result in a radiation dose of approximately 1 dpa. The targeted specimen surface temperature is approximately 1,100 °C.

Table 2. Rabbit irradiation test matrix showing the loading of specimens within each rabbit, the irradiation positions, and fill gas

Rabbit	Irradiation dose (dpa)	Specimens	Irradiation position	Fill gas
DC01	0.5	CVD-1, CVD-2, CVD-3, CVD-4, CVD-5, 4H-1, 4H-4, 4-01, 4-02, 4-03, 30-01, 30-02, 30-03, 32-01, 32-02, 32-03, 34-01, 34-02, 35-01, 35-02, 37-01, 37-02, 37-03, 37-04, 28-01, 28-05, Ag-01, Ag-02, 33-01	HT-4	Ne*
DC02	1	CVD-6, CVD-7, CVD-8, CVD-9, CVD-10, 4H-5, 4H-7, 4-04, 4-05, 4-07, 30-04, 30-05, 30-06, 32-04, 32-05, 32-06, 34-03, 34-04, 35-03, 35-04, 37-05, 37-06, 37-07, 37-08, 28-03, 28-04, Ag-03, Ag-04, 33-02, 33-03	HT-6	Ne*

* Or Ne equivalent

3. RABBIT CAPSULES ASSEMBLY

The two rabbits (DC01 and DC02) were assembled. Pictures of the parts layout for the two rabbits are shown in Figure 4. Figure 5 shows the specimens loaded in the cutouts of the graphite container and a top-down view of the container loaded in the housing. The signed capsule fabrication request forms are provided in APPENDIX A.

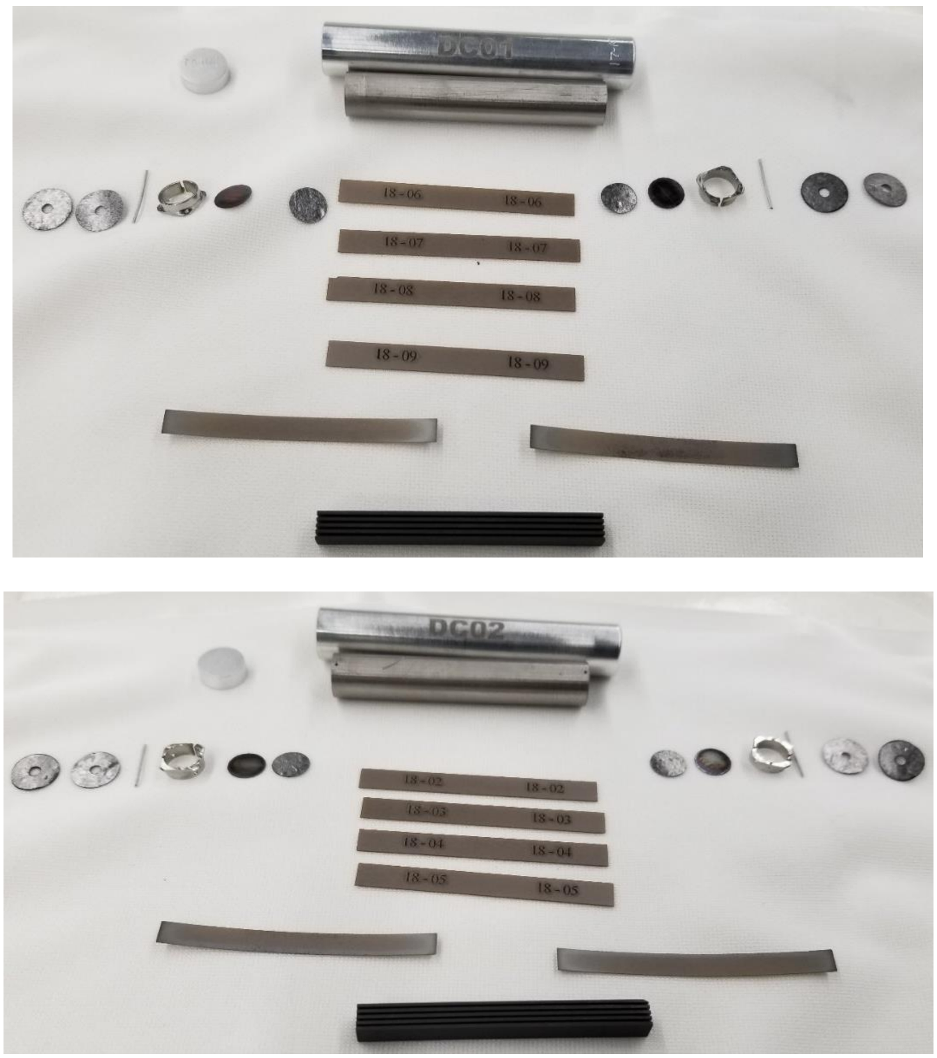

Figure 4. Parts layout for rabbit DC01 (top) and rabbit DC02 (bottom).

Figure 5. Specimens loaded in the container (left) and top-down view of the specimen container inserted in the housing (right).

All capsule components were dimensionally inspected and cleaned according to HFIR-approved procedures, drawings and sketches. After assembly of the internal components, the rabbit housing end caps were welded to the housings using an electron beam weld. The capsules were then places inside sealed chambers that were evacuated and backfilled with 40.5% He-Ar 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 40.5% He-Ar 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. Both rabbits passed helium leak testing and hydrostatic compression (see leak test report in APPENDIX A).

4. SUMMARY AND CONCLUSIONS

This report summarizes the capsule design and the irradiation test matrix for two rabbit capsules, which were successfully assembled to be inserted in the HFIR during cycle 481 (July 2018). Each capsule contains about 30 specimens of different types with fission product implantation. The specimens will be evaluated post-irradiation to determine their diffusion depth profiles. The rabbits were successfully assembled, welded and leak tested. Pictures of the rabbit assembly process are included in this report. Documentation of the capsule fabrication is provided in an appendix. For separation of the effects of radiation and temperature on the diffusion of fission products in the SiC layers of the specimens, a thermal experiment in the absence of irradiation will also be performed on the same types of specimens. Ultimately, the data gathered from these experiments will assist in the development of accurate models and codes for TRISO fuel performance, which are needed to ensure safe and efficient operation of this fuel for advanced reactor applications or for use as an accident-tolerant fuel for light water reactors (LWRs).

5. WORKS CITED

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3. S. Dwaraknath and G.S. Was, *Development of a multi-layer diffusion couple to study fission product transport in β-SiC.* Journal of Nuclear Materials, 2014. **444**(1-3): p. 170-174.
4. C.M. Petrie et al., *Design and Thermal Analysis for Irradiation of Pyrolytic Carbon / Silicon Carbide Diffusion Couples in the High Flux Isotope Reactor*, ORNL/TM-2017/390, Oak Ridge National Laboratory, Oak Ridge, TN, 2017

APPENDIX A. FABRICATION DOCUMENTATION FOR COMPLETED RABBITS

APPENDIX A. FABRICATION DOCUMENTATION FOR COMPLETED RABBITS

Capsule Number: DC01

Irradiation Conditions

Irradiation Location	HT	4
Target Fluence		1.18E+22
First Cycle Goal		481
Irradiation Time	5.0 days	
Irradiation Temperature		1,100°C
Fill Gas		40.5% He, Ar bal.

Approvals

	Request	Build
Performed by:	6/12/18	6/12/18
Checked by:	6/12/18	6/12/18

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	A	1	Al 6061	1		20713	20713	17-106	4.3249
Housing end cap	X3E020977A634	A	2	Al 4047	1		20714	20714	17-114	0.5164
Holder	S16-31-DIFFCOUPLE	1	1	Nb-1Zr	1		19733	20843	18-01	14.3481
Specimen Container	S16-31-DIFFCOUPLE	1	2	Graphite	1		19484	20844	18-01	1.2660
Centering Thimble	S16-30-DIFFCOUPLE	0	4	Ti-6Al4V	2		20093	20842	18-01	0.1421
									18-02	0.1432
Thermometry	S16-30-DIFFCOUPLE	0	3	SiC	4		19502	20849	18-06	0.2136
									18-07	0.2135
									18-08	0.2128
									18-09	0.2123
Specimen	S16-31-DIFFCOUPLE	1	3	Layers of SiC, with Ag, Pd, Eu or Sr	29	CVD-SiC-SC	20871	20871	CVD-1	0.010
									CVD-2	0.010
									CVD-3	0.011
									CVD-4	0.012
									CVD-5	0.011
						4H-SiC-SC			4H-1	0.009
									4H-4	0.010
						DCCD-4HSiC_MTS_SC-02			4-01	0.009
									4-02	0.010
									4-03	0.010
						DCCD-30			30-01	0.007
									30-02	0.006
									30-03	0.006
						DCCD-32			32-01	0.006
									32-02	0.005
									32-03	0.005
						DCCD-34			34-01	0.006
									34-02	0.007
						DCCD-35			35-01	0.006
									35-02	0.005
						DCCD-37			37-01	0.005
									37-02	0.004
									37-03	0.004
									37-04	0.004
						DCCD-28			28-01	0.006
									28-05	0.005
						DCCD-33			Ag-01	0.006
									Ag-02	0.007
						DCCD-33			33-01	0.007
Retainer Spring	S16-30-DIFFCOUPLE	0	2	SiC	2		19502	19502	2 total	0.2420
Support Disk	S16-30-DIFFCOUPLE	0	5	Moly	2	0.05-0.13 thick	20710	20710	2 total	0.0650
Wire	S16-30-DIFFCOUPLE	0	6	Moly	2	.5 diameter	19600	19600	2 total	0.0510
Insulator Disk	S16-30-DIFFCOUPLE	0	7	Grafoil	6	0.05-0.13 thick	19812	19812	6 total	0.0460
Quartz Wool	S16-30-DIFFCOUPLE	0	8	SiO2	AR	See note 10	20224	20279	N/A	0.0740
									Total Mass	22.2799
									Specimen Mass	0.2090
									Internal Mass	17.4386

Assembly

		Rev.	Comment
Assembly Drawing	S16-30-DIFFCOUPLE	0	
Welding & Cleaning	X3E020977A633	0	
Fill Gas	40.5% He, Ar bal.		

Capsule Number: DC02

Irradiation Conditions

Irradiation Location	HT 6
Target Fluence	2.59E+22
First Cycle Goal	481
Irradiation Time	11.0 days
Irradiation Temperature	1,100°C
Fill Gas	40.5% He, Ar bal.

Approvals

	Request	Build
Performed by:	6/12/18	6/12/18
Checked by:	6/12/18	6/12/18

Capsule Fabrication

	Drawing	Rev.	Part	Material	Count	Comment	MAT IR	FAB IR	ID	Mass (g)
Housing	X3E020977A634	A	1	Al 6061	1		20713	20713	17-109	4.3241
Housing end cap	X3E020977A634	A	2	Al 4047	1		20714	20714	17-77	0.5149
Holder	S16-31-DIFFCOUPLE	1	1	Nb-1Zr	1		19733	20843	18-03	14.4088
Specimen Container	S16-31-DIFFCOUPLE	1	2	Graphite	1		19484	20844	18-02	1.2418
Centering Thimble	S16-30-DIFFCOUPLE	0	4	Ti-6Al4V	2		20093	20842	18-03	0.1409
									18-04	0.1441
Thermometry	S16-30-DIFFCOUPLE	0	3	SiC	4		19502	20849	18-02	0.2116
									18-03	0.2131
									18-04	0.2103
									18-05	0.2130
Specimen	S16-31-DIFFCOUPLE	1	3	Layers of SiC, with Ag, Pd, Eu or Sr	30	CVD-SiC-SC	20871	20871	CVD-6	0.011
									CVD-7	0.011
									CVD-8	0.010
									CVD-9	0.010
									CVD-10	0.011
						4H-SiC-SC			4H-5	0.011
									4H-7	0.011
						DCCD-4HSIC_MTS_SC-02			4-04	0.008
									4-05	0.009
									4-07	0.010
						DCCD-30			30-04	0.007
									30-05	0.007
									30-06	0.007
						DCCD-32			32-04	0.005
									32-05	0.005
									32-06	0.005
						DCCD-34			34-03	0.006
									34-04	0.006
						DCCD-35			35-03	0.006
									35-04	0.006
						DCCD-37			37-05	0.004
									37-06	0.005
									37-07	0.005
									37-08	0.005
						DCCD-28			28-03	0.005
									28-04	0.006
						DCCD-33			Ag-03	0.006
									Ag-04	0.006
						DCCD-33			33-02	0.007
									33-03	0.005
Retainer Spring	S16-30-DIFFCOUPLE	0	2	SiC	2		19502	19502	2 total	0.2420
Support Disk	S16-30-DIFFCOUPLE	0	5	Moly	2	0.05-0.13 thick	20710	20710	2 total	0.0650
Wire	S16-30-DIFFCOUPLE	0	6	Moly	2	.5 diameter	19600	19600	2 total	0.0500
Insulator Disk	S16-30-DIFFCOUPLE	0	7	Grafoil	6	0.05-0.13 thick	19812	19812	6 total	0.0460
Quartz Wool	S16-30-DIFFCOUPLE	0	8	SiO2	AR	See note 10	20224	20279	N/A	0.0710
									Total Mass	22.3126
									Specimen Mass	0.2160
									Internal Mass	17.4736

Assembly

		Rev.	Comment
Assembly Drawing	S16-30-DIFFCOUPLE	0	
Welding & Cleaning	X3E020977A633	0	
Fill Gas	40.5% He, Ar bal.		

Report Number: 61818-1

ACCREDITED

LEAK TEST REPORT

Test Requested by: LE COQ	Allowable Leak Rate: < 1E-7 (He) Std-Atm-cc/s
Date Requested: 6/18/18	Date Required: 6/18/18
Work Order Number: 338221	Test Pressure Req. Across Boundary: -1 ATM
Item Tested: 2 EA IRR CAPS DC01, DC02	Customer: RNSD
Specification: AP-RNSD-20977-020, R5 NDE 70, Rev: 7	Technique Used: INSIDE - OUT Rev: 0 ☒ Inside - Out ☐ Outside - In

EQUIPMENT

LEAK DETECTOR		STANDARD LEAK	
Make and Model: ADIXEN ASM 182TD+		Manufacturer: VEECO	Tracer Gas: He
Serial Number: HLD 0860605		Model: SC-1	Serial Number: ~~M138854~~ 15220
		Leak Rate: 2.09E-8 Atm-cc/s @ -1 atm @23.9 °C	
TEST GAUGES		Correlation Formula: $[1 - (T_{cal} - T_{surf}) C_T] LR$	Temp Coefficient: 3.0 %/°C
Temp Gauges: A005445	Due: 11/13/18	Correlated LR: 2.15E-8 Atm-cc/s @ -1 atm @ 24.2 °C	
Pressure Gauges: N/A	Due: —	Calibration Due Date: 9/22/18	

RESULTS ☒ Quantitative ☐ Semi - Quantitative

MACHINE CALIBRATION	SYSTEM TEST CONDITIONS
System Pressure: < 3E-3 MB	System Temperature: 24.2 °C ☒ Surface ☐ Internal Gas
Background: < 1E-9 Atm-cc/s	delta P Test Boundary: -1 ATM
Leak Response: 2.1E-8 Atm-cc/s	Tracer Gas: He % Concentration: 40.56
Minimum Detectable Leak: 1E-9 Atm-cc/s	System Response Time: < 5 SEC
System Sensitivity: 2E-9 Atm-cc/s	System Response: 2.8E-9 Atm-cc/s
Response Time: < 5 SEC	Duration of Test: ~ 5 MIN
Aux. Equipment: BELL JAR	
☒ ACCEPT ☐ REJECT ☐ SKETCH / DATA ATTACHED	System Leak Rate: w/ stated tracer gas ~~4.1E-9~~ Atm-cc/s @ 1 atm @ 24.2 °C 6.9E-9

COMMENTS: CF = 1.68 / 2.47
- PRE HYDRO LT

Test Conducted By: J PRYOR [signature] Level: III Date: 6/18/18 Time: 10:30A

PRESSURE TEST REPORT

ITEM TESTED: 2 EA IRR CAPS DC01 DC02		MJR NUMBER:	LOCATION: (if installed)
		DRAWING NUMBER:	CHARGE NUMBER: 3905N622
TEST PRESSURE REQUIRED: 1035 PSIG	SAFETY WORK PERMIT NO. (if required): NA	PRESSURE SOURCE USED: HAND PUMP	TEST REQUESTED BY: JEFF PRYOR

TEST MEDIUM: [X] WATER ☐ NITROGEN ☐ AIR ☐ OTHER

LEAK TEST METHOD USED: ☐ VISUAL ☐ ULTRASONIC ☐ BUBBLE ☐ PRESSURE DECAY

PRE-TEST CHECKLIST

OVER-PRESSURE PROTECTION REQUIRED: [X] YES ☐ NO

WELDED JOINTS PAINTED OR INSULATED: ☐ YES [X] NO

HAS AIR BEEN BLED FROM VESSEL (HYDROSTATIC TEST ONLY): [X] YES ☐ NO

TEST GAUGE DATA

	SERIAL NUMBER	MANUFACTURER	CAL. DATE	RANGE	SUBDIVISIONS
PRESSURE GAUGE #1	MTE 564	BEAMEX	10-11-17	0-2400 psig	0.1 psig
PRESSURE GAUGE #2	NA	NA	NA	psig	psig
TEMPERATURE GAUGE	AMBIENT ROOM	70°F approx.		°F	°F

TEST RESULTS

TIME	PRESSURE GAUGE #1	PRESSURE GAUGE #2	TEMPERATURE	INITIALS	TIME	PRESSURE GAUGE #1	PRESSURE GAUGE #2	TEMPERATURE	INITIALS
1:09	1070.2	— psig	— °F	BB	1:26	1078	— psig	— °F	BB
1:24	1051.1	— psig	— °F	BB	1:41	1070.1	— psig	— °F	BB
1:25	0	— psig	— °F	BB	1:42	0	— psig	— °F	BB
—	—	— psig	— °F	—	—	—	— psig	— °F	—

INITIAL METAL TEMPERATURE NA °F + 460 = ______ °R

FINAL METAL TEMPERATURE NA °F + 460 = ______ °R

Final Pressure (psig) [Initial Temperature (Degrees R) / Final Temperature (Degrees R)] = Adjusted Pressure (psig)

______ psig [______ Degrees R INITIAL / ______ Degrees R FINAL] = ______ psig

FOR PNEUMATIC TEST ONLY

FINAL ADJUSTED PRESSURE = NA (psig)*

POST TEST CALIBRATION ACCEPTABLE: (Require for single gauge tests) ☐ YES ☐ NO [X] N/A

TEST RESULTS: [X] ACCEPTABLE ☐ UNACCEPTABLE

REMARKS:

INSPECTOR (Print & Sign Name, Level)

BRAD BROWN Brad Brown

Date: 6-18-18

* For Pneumatic Test Only.

FORM NDE-80-1, Rev. 0

IDMS: 20329

FORM A-3 — FINAL CAPSULE HYDROSTATIC PRESSURE TEST WORKSHEET

CAPSULE ID	MASS Pre-test	Post-test	Gain/Loss
DC01	22.552	22.552	0
DC02	22.457	22.457	0

Report Number: 6/18/18-2

A2LA ACCREDITED

LEAK TEST REPORT

Test Requested by: LE COQ	Allowable Leak Rate: < 1E-7 (He) Std-Atm-cc/s
Date Requested: 6/18/18	Date Required: 6/18/18
Work Order Number: 338211	Test Pressure Req. Across Boundary: ~1 ATM
Item Tested: LEA IRR CAPT DC01, DC02 AP-RNSD-20977-?	Customer: RNSD
Specification: AP-RNSD-20977-DC0-R5 / NDE 70, Rev: 7	Technique Used: INSIDE-OUT / Rev: 0 / ☒ Inside - Out ☐ Outside - In

EQUIPMENT

LEAK DETECTOR		STANDARD LEAK	
Make and Model: ADIXEN ASM 182 TD+		Manufacturer: VEECO	Tracer Gas: He
Serial Number: HLD 0860905		Model: SC4	Serial Number: 15220
		Leak Rate: 2.04E-8 Atm-cc/s @ ~1 atm @ 23.6 °C	
TEST GAUGES		Correlation Formula: $[1 - (T_{cal} - T_{surf}) C_T] LR$	Temp Coefficient: 3.0 %/°C
Temp Gauges: A005945	Due: 11/13/18	Correlated LR: 2.13 E-8 Atm-cc/s @ 1 atm @ 24.6 °C	
Pressure Gauges: N/A	Due: ~	Calibration Due Date: 9/22/18	

RESULTS

☒ Quantitative ☐ Semi - Quantitative

MACHINE CALIBRATION		SYSTEM TEST CONDITIONS	
System Pressure: < 3E-3 MB		System Temperature: 24.6 °C ☒ Surface ☐ Internal Gas	
Background: < 1E-9	Atm-cc/s	delta P Test Boundary: ~1 ATM	
Leak Response: 2.1E-8	Atm-cc/s	Tracer Gas: He	% Concentration: 40.5
Minimum Detectable Leak: 1E-9	Atm-cc/s	System Response Time: < 5 SEC	
System Sensitivity: 2E-9	Atm-cc/s	System Response: < 1E-9	Atm-cc/s
Response Time: < 5 SEC		Duration of Test: ~ 5 MIN	
Aux. Equipment: BELL JAR			
☒ ACCEPT ☐ REJECT ☐ SKETCH / DATA ATTACHED		System Leak Rate: (w/ stated tracer gas) < 1E-7 Atm-cc/s @ ~1 atm @ 24.6 °C	

COMMENTS: CF = 1.68 @ 2.47
- AFTER HYDRO

Test Conducted By: J PRYOR [signature]	Level: III	Date: 6/18/18 Time: 2:00P

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