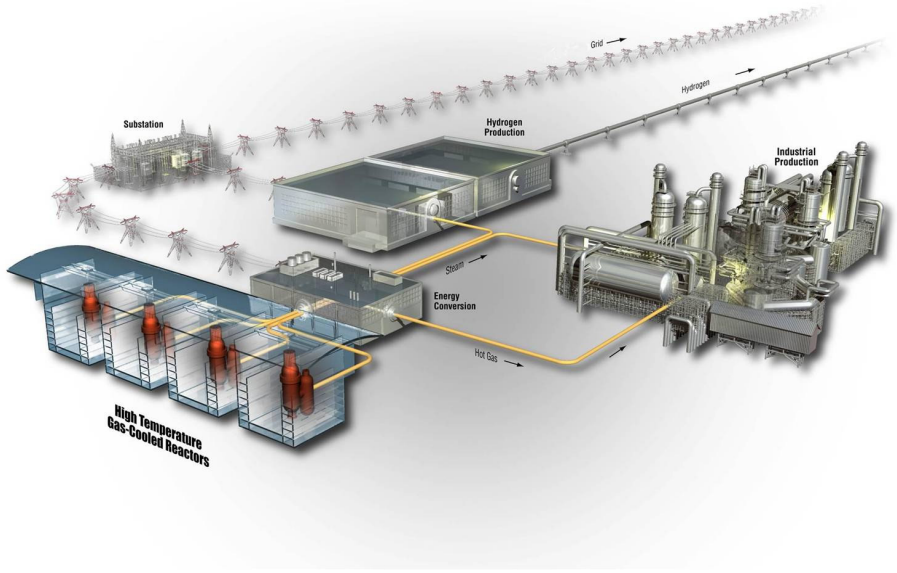
INL/EXT-14-32060
Revision 0

AGC-2 Disassembly Report

W. E. Windes, P. L. Winston, and W.D. Swank

May 2014



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http://www.inl.gov

Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

VHTR Program

AGC-2 Disassembly Report

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May 2014

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ABSTRACT

The Very High Temperature Reactor (VHTR) Graphite Research and Development Program is currently measuring irradiated material property changes in several grades of nuclear graphite to predict behavior and operating performance within the core of these new high temperature reactor designs. The Advanced Graphite Creep experiment, consisting of six irradiation capsules, will generate the irradiated graphite performance data for VHTR reactor operating conditions. All six capsules in the experiment will be irradiated in the Idaho National Laboratory (INL) Advanced Test Reactor (ATR), disassembled in the INL Hot Fuel Examination Facility, and examined at the INL Research Center. This is the disassembly report describing the disassembly, shipment, post-irradiation inspection, and storage of the graphite specimens contained within the AGC-2 irradiation test series capsule (the second irradiation capsule of the series). The second capsule (AGC-2) began irradiation on ATR Cycle 149A on April 12, 2011, and ended with ATR Cycle 151B on May 5, 2012. A maximum dose of approximately 5 dpa was achieved. The capsule was removed from the ATR area and transferred in August 2013 to the Hot Fuel Examination Facility. Disassembly and specimen extraction began February 10, 2014, and the graphite specimens were shipped to the IRC in March 2014. Each specimen was visually inspected, inventoried, and placed into the irradiated graphite storage vault. Graphite specimens in the vault are now ready for post-irradiation examination and testing. This report summaries the disassembly, shipping, post-irradiation visual inspection, and inventory of the AGC-2 graphite specimens.

CONTENTS

FIGURES

ACRONYMS

AGC	Advanced Graphite Creep
ASME	American Society of Mechanical Engineers
ATR	Advance Test Reactor
CCL	Carbon Characterization Laboratory
HFEF	Hot Fuel Examination Facility
HOPG	Highly Oriented Pyrolytic Graphite
INL	Idaho National Laboratory
IRC	INL Research Center
MFC	Materials and Fuels Complex
NGNP	Next Generation Nuclear Plant
OD	Outer Diameter
PIE	Post-Irradiation Examination
Pre-IE	Pre-irradiation Testing
R&D	Research and Development
SiC	Silicon-Carbide

AGC-2 Disassembly Report

1. DESCRIPTION OF AGC EXPERIMENT

The Next Generation Nuclear Plant (NGNP) Graphite Research and Development (R&D) Program is currently measuring irradiated material properties for predicting the behavior and operating performance of new nuclear graphite grades available for use within the cores of new very high temperature reactor designs. The Advanced Graphite Creep (AGC) experiment, consisting of six irradiation capsules, will generate irradiated graphite performance data for NGNP reactor operating conditions. The AGC experiment is designed to determine the changes to specific material properties such as thermal diffusivity, thermal expansion, elastic modulus, mechanical strength, irradiation-induced dimensional change rate, and irradiation creep for a wide variety of nuclear grade graphite types over a range of high temperature and moderate doses. A series of six capsules containing graphite test specimens will be used to expose graphite test samples to a dose range from 1 to 7 dpa at three different temperatures (600, 900, and 1200°C) as described in the Graphite Technology Development Plan.[1] Since irradiation-induced creep within graphite components is considered critical to determining the operational life of the graphite core, some of the samples will also be exposed to an applied load to determine the creep rate for each graphite type under both temperature and neutron flux.

All six AGC capsules in the experiment will be irradiated in the Advanced Test Reactor (ATR). AGC-1 and AGC-2 will be irradiated in the south flux trap and AGC-3–AGC-6 will be irradiated in the east flux trap. The change in flux traps is due to NGNP irradiation priorities requiring the AGC experiment to be moved to accommodate fuel irradiation experiments. After irradiation, all six AGC capsules will be cooled in the ATR Canal, sized for shipment, and shipped to the Materials and Fuels Complex (MFC) where the capsule will be disassembled in the Hot Fuel Examination Facility (HFEF). During disassembly, the metallic capsule will be machined open and the individual samples removed from the interior graphite body containing the samples. Samples removed from the capsule will be loaded in a shipping drum and shipped to the Idaho National Laboratory (INL) Research Center (IRC) for initial post-irradiation examination (PIE) and storage for any future testing at the newly completed Carbon Characterization Laboratory (CCL). All work was performed under an ASME NQA-1-2008;1a-2009 compliant quality assurance program.

The CCL is located in Labs C-19 and C-20 of IRC. It was specifically designed to support graphite and ceramic composite R&D activities.[2] The CCL is designed to characterize and test low activated irradiated materials such as high-purity graphite, carbon-carbon composites, and silicon-carbide (SiC) composite materials. The laboratory is fully capable of characterizing material properties for both irradiated and nonirradiated materials. All test specimens from each of the six capsules will be processed through the CCL to visually inspect each sample, perform initial dimensional changes, and repackage the samples for shielded storage in the NGNP irradiated graphite vault located in Lab C-19.

2. AGC-2 Status

Activities for AGC-2 began in 2010 with the pre-irradiation testing (Pre-IE) of all graphite samples to be inserted into the AGC-2 capsule. After Pre-IE sample testing was completed, the samples were loaded into the AGC-2 capsule then inserted into the ATR. Capsule irradiation began on ATR Cycle 149A on April 12, 2011, and ended with ATR Cycle 151B on May 5, 2012. After irradiation the top and bottom ends of the capsule were sectioned in July 2013 to allow the sample section to be inserted into a GE2000 shipping cask. The capsule was shipped to MFC in August 2013 and disassembly was performed in the HFEF main cell from February through March 2014. Graphite samples were shipped to the IRC in March 2014, and post-irradiation inspection and specimen inventory were conducted from March to May 2014. Post irradiation examination (PIE) testing of the specimens will continue in the CCL after May 2014.

2.1 Preirradiation Examination of AGC-2 Samples

A complete preirradiation testing and characterization program was conducted in 2010 on all graphite samples inserted into AGC-2 capsule.[3] The properties measured were bulk density by mensuration, electrical resistivity, and elastic constants, including dynamic Young's modulus (fundamental frequency method); sonic elastic constants, including Young's modulus, shear modulus, and Poisson's ratio; ambient temperature thermal conductivity; and Thermal Expansion (RT-800°C). Samples were inserted in the AGC-2 capsule in the summer of 2009 before irradiation.

2.2 Irradiation of AGC-2 Capsule

The AGC-2 capsule was irradiated in the south flux trap of the ATR from September 5, 2009 to January 8, 2011 spanning seven irradiation cycles (approximately 378 effective full-power days). The irradiation data qualification report summarizes the AGC-2 irradiation history.[4]

After the flux wires have been analyzed and the temperature model finalized through verification and validation, specific data on the temperature, dose, and applied stress levels of the loaded samples will be reported in a future AGC-2 irradiation experiment Engineering Calculation and Analysis Report.

2.3 Disassembly of AGC-2 Capsule

After irradiation, completed on May 5, 2012, the AGC-2 capsule was stored in the ATR Canal to allow the activity of the steel pressure tube section of the capsule to decay to lower levels. After radioactive cooling, the ends of the capsule were sectioned to remove the upper pneumatic ram compressive loading components and the lower pressure tube, including the stack stirring pneumatic bellows. The sectioning was performed using a remotely operated band saw in the ATR Dry Transfer Cubicle. The sectioned capsule was shipped to MFC in August 2013 and disassembly was performed in the HFEF main cell from February through March 2014.

The interior of the AGC-2 capsule was constructed of four graphite body sections approximately 2 inches in diameter by 12 inches long (for a total length of approximately 49 inches before irradiation), held together by intricate bayonet joints.[5,6,7,8,9,10,11,12,13] Seven channels were machined axially down the length of the graphite body; one central channel and six on the outer radius surrounding the central channel. Graphite samples in the six radial channels of the upper half of the graphite body were compressively stressed while the graphite samples in the lower half were left unloaded as control samples. The samples in the central channel, upper and lower halves, were unstressed. Twenty-six spacer samples containing flux wires were located in upper, middle, and lower positions within the six radial channels to ascertain the accumulated dose in the samples throughout the capsule. The top and bottom halves were separated at the graphite body centerline, but pistons between each half transmit the pneumatic force from the stack stirring pneumatic bellows to allow the test samples in each stack to be stirred during reactor shutdown and outages. A center channel running the entire length of the graphite body contained unstressed piggyback samples, which consisted of small thermal test buttons of the five main graphite grades, experimental graphite grades, and Highly Oriented Pyrolytic Graphite (HOPG) specimens.

All test specimens (1-inch long creep and 1/4-inch long piggyback) and flux wire spacers were extracted from the AGC-2 test train capsule during disassembly. All test specimens were shipped to the IRC for visual inspection, specimen inventory, and placement into the irradiated graphite storage vault in Lab C-19. The flux wires, flux wire spacer bodies, and graphite body will be held at the MFC for analysis and eventual disposition.

2.3.1 AGC-2 Capsule Disassembly Activities

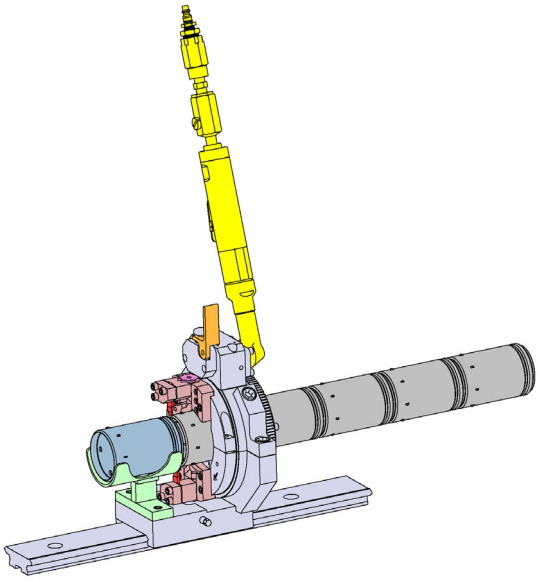
The AGC-2 test train capsule was disassembled within the HFEF main hot cell due to the high radiation levels from the steel pressure tube and other metal components of the test train. A summary of

the AGC-2 disassembly highlights is presented here with a detailed activity log of the specific disassembly actions given in Appendix B.

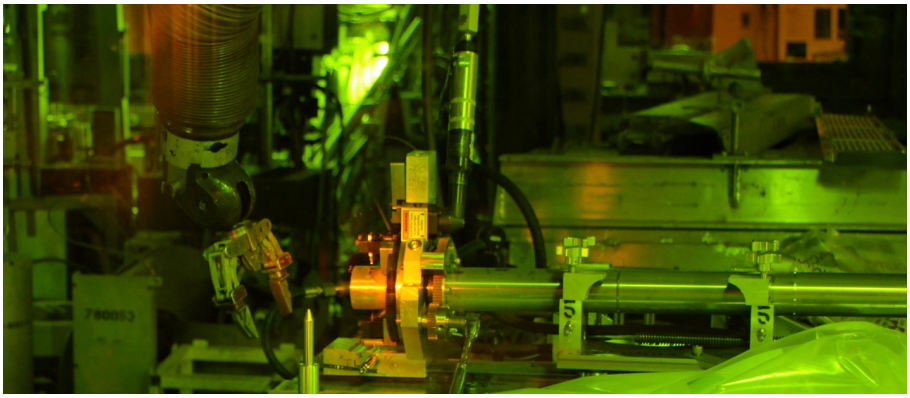
The general AGC-2 disassembly task sequence was planned as follows:

1. Remove the graphite body containing the samples from the heavy steel pressure boundary tube.
2. Remove the gas lines that actuated the lower section stack upset bellow.
3. Remove the 12 thermocouples that penetrated to each elevation in the graphite body.
4. Push out the continuous stack of 0.25-inch-thick piggyback samples from the center position of the graphite body.
5. Push the individual radial position creep samples into a sorting station for visual identification by sample number.
6. Separate the spacers containing the flux wires from the test specimens for individual analysis.
7. Insert all graphite specimens into a Lexan tube to protect the samples from contamination in the HFEF and against damage during transport to the CCL.
8. Perform physical measurement of the graphite body. The length and outer diameter was measured at various positions for each section length. The diameter of all channels in the top half and bottom half of the graphite body were measured after the specimens were extracted. All measurements were to determine the irradiation induced dimensional change within the graphite body to assist in the design of AGC-5 test train capsule.

AGC-2 disassembly began February 10 when the test train capsule was moved to the disassembly table and secured in place. A new pipe cutter attachment was designed to remove the outer steel pressure tube based upon lessons learned from AGC-1 disassembly (Figure 1). The new pipe cutter was used to cut and remove the bottom cap of the steel pressure vessel. After cap removal, an attempt to push the entire graphite body out of the pressure tube was initiated without success. It was concluded that the graphite body was physically stuck inside the pressure tube just above where the cap was cut off.



(a)



(b)

Figure 1. (a) Schematic of pipe cutter tool and (b) pipe cutter in use during cutting operations of the pressure tube.

A later cut was completed, approximately 3 inches from the bottom cap end cut. The graphite body inside the pressure tube appeared to be intact and could be seen to move inside the steel tube during cutting operations. To remove the graphite body, the steel tube was slid laterally while holding the graphite body in place (Figure 2). During initial pressure tube separation, the graphite body cracked at one of the section joints. Seeing the section begin to separate led to the decision to remove the lower graphite body section from the main disassembly table to the sorting table and push out the samples into shipping tubes so as to limit the possibility of contamination or loss of samples. The remaining graphite body sections were pushed out of the steel pressure tube with a custom-made pushplug, which pushed across the entire end of the graphite body. This pushplug design resulted from lessons learned during AGC-1 disassembly to keep the graphite body from cracking and separating while still in the steel pressure tube. During graphite body extraction, the thin steel shim stock heat shield was pushed out with the graphite body (Figure 3).

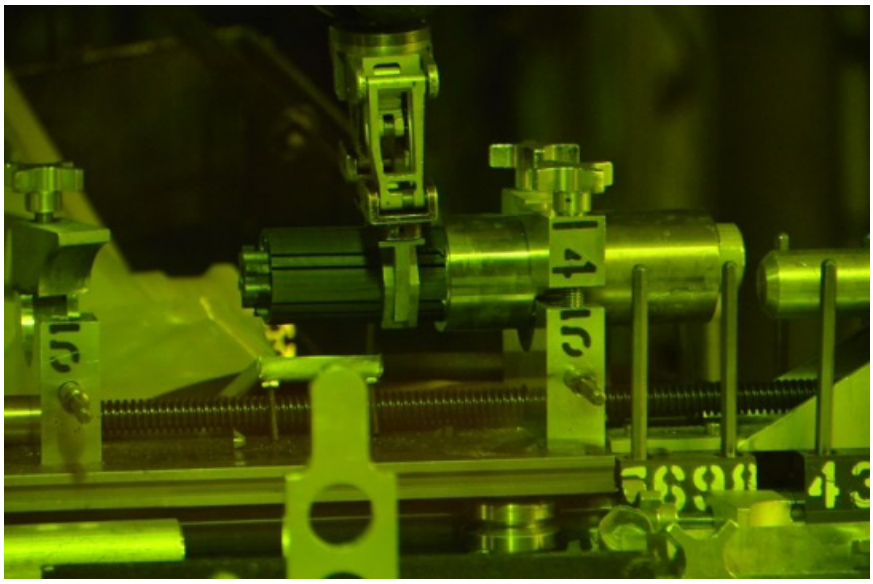


Figure 2. Image of graphite body inside pressure tube during cutting operation.

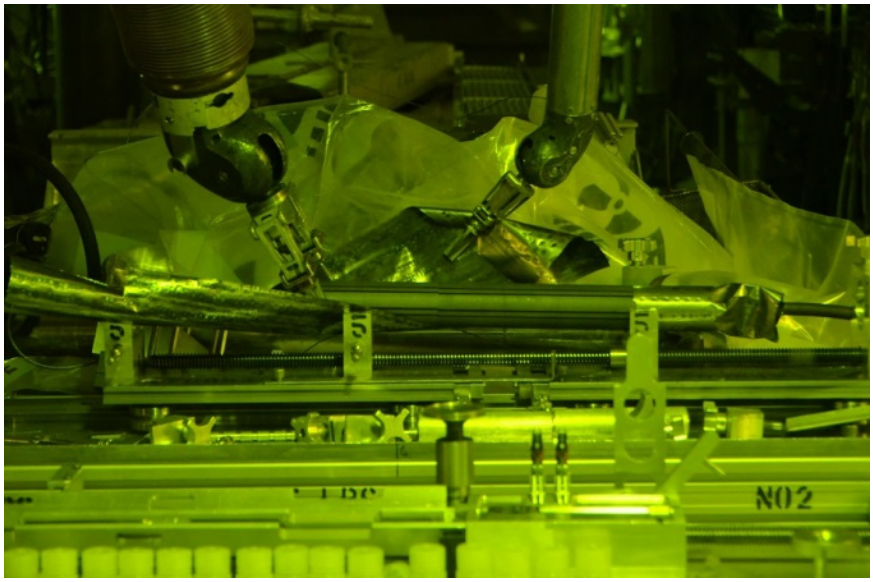


Figure 3. Thin stock metal heat shield being removed from graphite body.

After the graphite body sections were removed from the pressure tube, they were individually lifted with the master-slave manipulator and transferred to the radial position insert of the sorting table (Figure 4). Once secured on the sorting table, a receiving tube was mounted onto the receiving end of the sorting table tray to receive specimens pushed out from the graphite body (Figure 5). Specimens from both radial channels and the center channel were pushed from the graphite body sections, visually identified by their unique laser engraved ID number, and inserted into a numbered transport tube. All graphite specimens contained within each uniquely identified transfer tube were identified and listed in the shipping records.

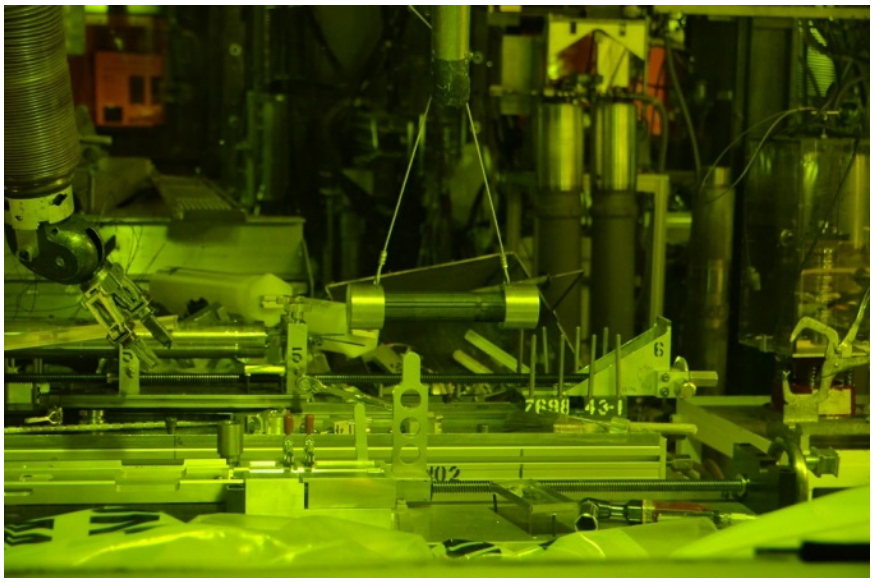
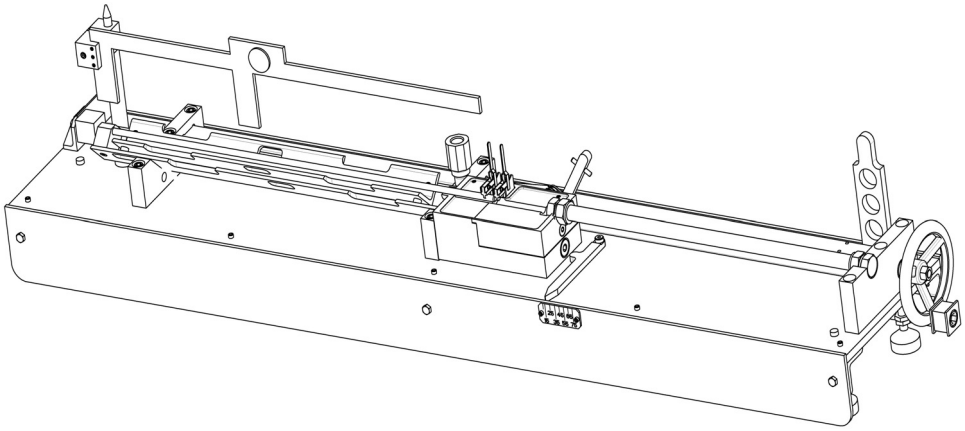
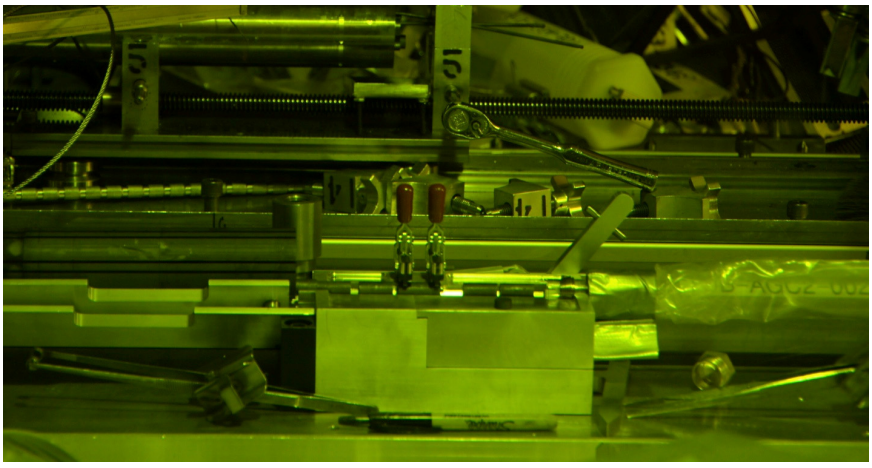


Figure 4. Graphite body section being manually transferred to sorting table.



(a)



(b)

Figure 5. (a) Schematic of newly designed sorting table and (b) sorting table holding graphite body section (left side of image) and transport tube attached ready to receive extracted specimens. (Tube is visible on right; red handles in middle hold samples for flux wire spacer removal.)

Flux wire spacers were separated from the radial channel specimens and placed in uniquely identified 30-ml poly bottles for flux wire analysis at a later time. The flux wires have been stamped with unique identification numbers to determine their position within the AGC-2 test train capsule. However, the radial creep specimens directly adjacent to each flux wire spacer were recorded on the 30-ml storage bottles to ensure their position within the test train. Flux wires were removed from the spacers and placed in smaller cryo-vials for easier shipping and direct gamma ray counting. All flux wires will be analyzed to verify the accumulated dose calculations. Analysis results will be recorded within the AGC-2 Irradiation Reports.[14,15,16]

Three AGC-3 specimens were lost during disassembly: one HOPG specimen and two piggy back "button" specimens. During specimen extraction, HOPG sample container M1-05 came open and the HOPG specimen inside the container was lost. This problem was corrected for later HOPG graphite containers by redesigning the containers with threaded lids. Piggy back samples S101 and CPB31 were lost during the process of cutting and removing steel and graphite end cap components. No creep or creep reference specimens from major grades of graphite were lost.

The radiation levels of all transport tubes containing the graphite test specimens were surveyed. The maximum individual tube dose rate was reported as 200 mR/hr. All transport tubes were loaded into the AGC shielded shipping drum and shipped to the CCL at IRC. A complete inventory of specimens contained within each transport tube was included in the AGC-2 shipment to the CCL.

After removing all graphite specimens and flux wire spacers, dimensional measurements of the graphite body sections were performed (Figure 6). The various sections were placed on the sorting table tray and the Vernier caliper was used to check each section's length. The sections were measured at three different points, rotating 120 degrees between measurements. The caliper operation was consistent, allowing the pieces to be held in a good orientation, but the results were inconsistent, in that the measurements at several points were not repeatable. This suggests that the process of separating the sections deforms the joint in a way that makes definitive measurements problematic.

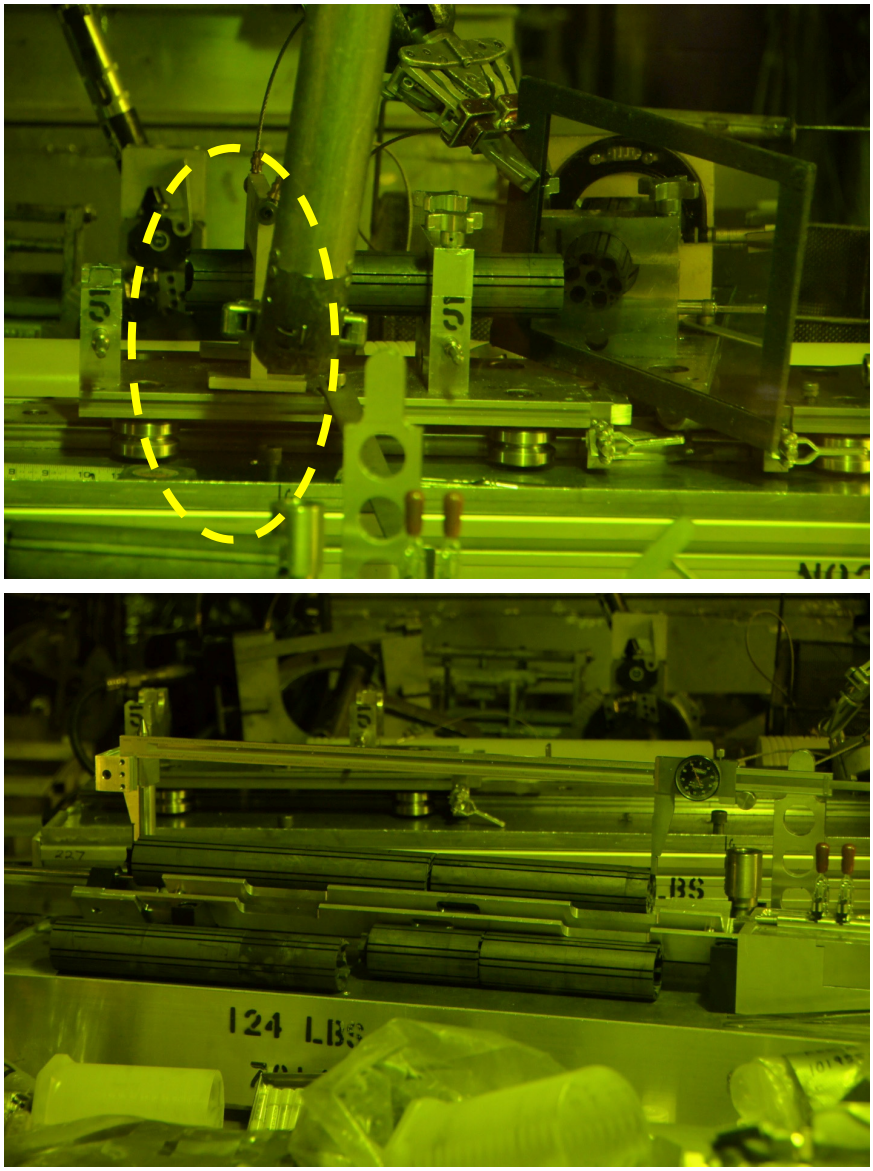


Figure 6. Image of caliper measuring graphite body (upper image measuring outside diameter, lower image, overall length).

Utilizing the same micrometer used for AGC-1, the AGC-2 graphite body outer diameter was determined. As with the overall length measurements, the outer diameter (OD) was checked at two different positions around the circumference.

The final graphite body measurement was determination of the central and radial channel borehole diameters using a bore gauge. To give an operational baseline, the bore gauge was inserted into a 0.516-in. inside diameter steel standard and the measurements in the graphite body were recorded as either a plus or minus value above or below the 0.516-in. inner diameter (ID) standard (Figure 7). The bore diameters of channels in the upper part of the AGC-2 test train capsule are larger than the standard diameter. The bore diameters of channels in the lower part of the test train were smaller than the standard.

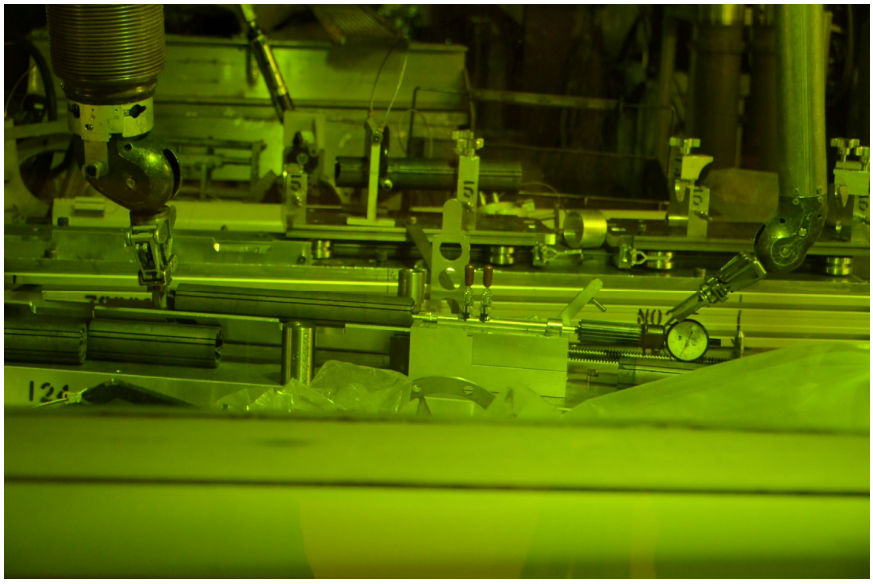


Figure 7. Image of bore hole gauge measuring diameter of inner channel.

This difference in channel bore diameter trends can be explained by the design of the AGC-2 capsule and through the irradiation response of graphite. The AGC capsules are designed to load the graphite creep specimens in the top section of the capsule in compression during irradiation to cause conditions for creep to occur. The applied load in the top half of the capsule is distributed to the bottom half of the graphite body to keep the graphite creep specimens in the bottom half unloaded (and unstressed) as the control specimens.[10]

The top half of the graphite body is, therefore, unstressed and only suffers from irradiation dimensional change, which tends to make graphite denser under irradiation. As a consequence, the bore openings in the channels will slightly increase as the graphite changes dimensionally. The bottom half of the graphite body is under stress imposing irradiation induced creep conditions. During irradiation, the compressive creep specimens tend to shrink in the axial direction but there is a slight lateral swelling that occurs due to the Poisson effect. This “barreling” of the specimens during irradiation creep is well documented and occurs because of the irradiation induced strain/creep along with the compressive stresses. The lower half of the graphite body is under compressive stress during irradiation, and this barreling effect would be expected inside the channels. The overall lateral dimension change is small due to the lower compress stress state experienced by the lower graphite body, but it is enough to create a smaller bore channel opening in all channels. All graphite body measurements are provided in Appendix C.

2.3.2 Conclusions from AGC-2 Capsule Disassembly Activities

The pipe cutter option produces considerably less loose chips that can be inadvertently transferred with the samples. The pipe cutter will be utilized for future AGC capsule disassembly activities. Additional modifications of the disassembly table will be necessary based upon lessons learned through operation of the pipe cutter (Alignment of the steel pressure tube within the rail carriages, greater clamping pressure during cutting, and correct operation of the cutter to ensure clean chip removal during cutting operation). The base design (INL designed and fabricated) that clamps the cutter to the rail uses two 1/4-20 bolts that loosened during the second cut to the pressure tube, allowing it to vibrate when uneven cutting occurred. This component needs to be redesigned, either to allow the cutter to be self-adjusting with respect to the piece being cut, or to be more rigid to resist misalignment.

The sorting table is a significant improvement over the previous designs, having a minimal number of parts to operate, and being essentially self-centering. Some small alignment modifications to the pushrod activity is recommended. The self-adjusting De-Staco clamps used for holding the samples during separation of flux wire spaces do not apply as much force as might be ideal, presumably due to shrinkage of the specimen OD. A remote means to adjust the clamps would be ideal, but not an absolute requirement.

The graphite body length caliper appears to work well, and probably needs no modification. However, measuring the overall length of the graphite body provides minimal information since small sections from the top half and the bottom half of the graphite body are removed during sizing operations before transport to the disassembly hot cells. An accurate measurement of the remaining pieces is not possible after this operation takes place. The micrometer used to measure graphite body OD requires minor modifications to improve operability and flexibility. It may be fairly straightforward to produce a Vernier caliper that can be easily read when the graphite body is placed on the sorting table. The bore gauge was designed to work with the sorting table and required minimal effort to perform the measurements.

2.4 Visual inspection, inventory, and storage of AGC-2 specimens

The AGC shipping drum containing the AGC-2 graphite test specimens was received at the CCL March 19, 2014. Visual inspection, inventory, and storage of each specimen within the irradiated graphite storage vault began on March 24, 2014.

After receiving the specimens from HFEF, IRC personnel unloaded the transfer tubes from the Type A shielded shipping drum (Figure 8). The tubes were loaded one at a time into the antechamber of a radiologic glove box located in the CCL (Figure 9 and Figure 10). Once inside the glove box, the individual specimens were unloaded from the transfer tubes and visually inspected. Visual inspection is documented in six photographs of each specimen Figure 11. The first four photographs are of the sides of each sample at 90-degree intervals. The final two photographs are of the top and bottom surfaces. Any chips, cracks, breakage, or damage to the specimen are noted in the laboratory notebook. Two formats of each image are stored. The CR2 format is the Canon raw data that contains the image and all associated camera settings. This file must be read by Canon EOS utility software. The second image is in JPG format and can be read by almost all digital photograph viewing software. The camera used was a Canon EOS40D with a Canon Ultrasonic180-mm focal length lens. The following settings were used for all pictures:

- Shutter speed = 0.3 sec
- F-stop = F32
- Color Temperature = 2900K
- Simulated Film speed = 1000 ISO
- Quartz halogen lighting from outside the glove box.

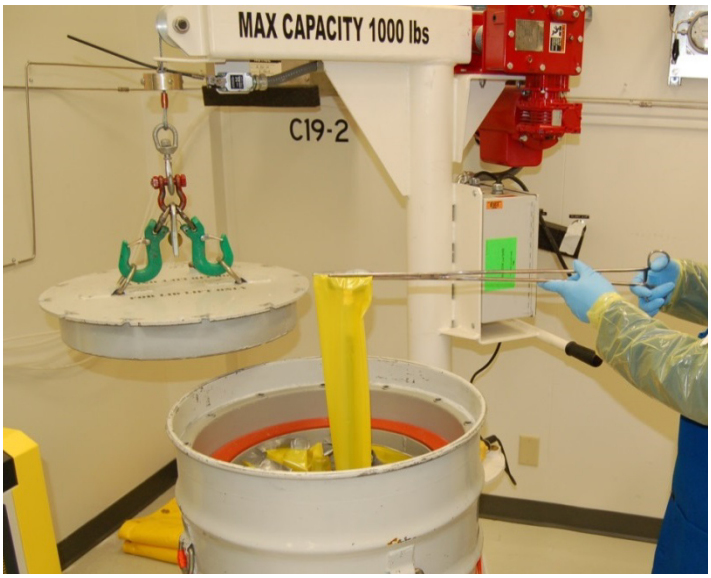


Figure 8. Plexiglas tube of specimens being unloaded from Type A shipping drum.

Figure 9. CCL radiologic glove box used to visually inspect graphite samples, photograph, and repackage samples for storage.

Figure 10. A single Plexiglas tube of specimens along with their corresponding snap caps placed in the antechamber for transfer into the glove box.

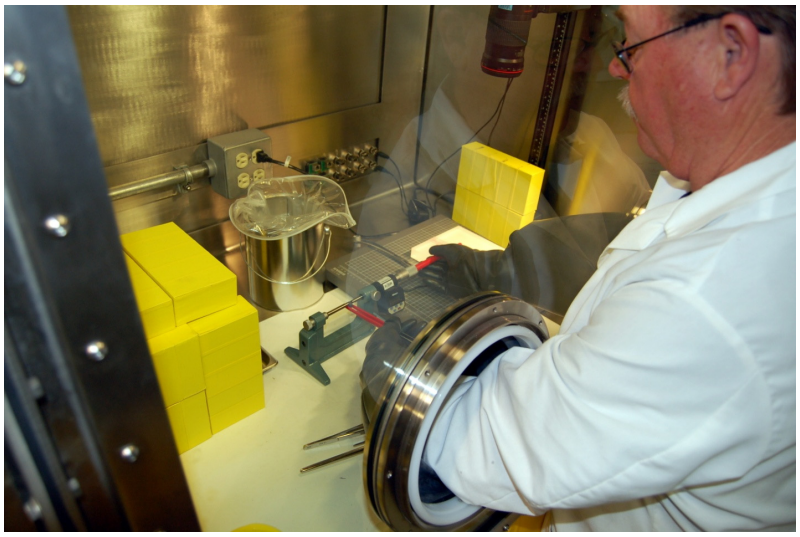


Figure 11. Inspection, photography and transfer of specimen to plastic snap cap storage containers.

Figure 12 shows the representative images of a specimen. No significant damage to the initial samples was observed during visual inspection. When comparing the images to pre-irradiation visual inspection images, many of the samples were observed to have additional surface markings, such as minor longitudinal scratches. These marks appeared to be superficial, most likely resulting from handling during disassembly and sorting. More detailed inspection of the marks will be performed if further testing indicates a significant flaw. Many samples also appeared to have a rougher surface after irradiation. This increased surface roughness may arise from the significant dimensional changes of the individual crystallites at the surface. Due to the random crystal orientation in the near isotropic graphite grades, some of the crystallites will shrink under irradiation, while some will expand away from the original surface plane and create a rougher surface. These samples will be analyzed further in the future.

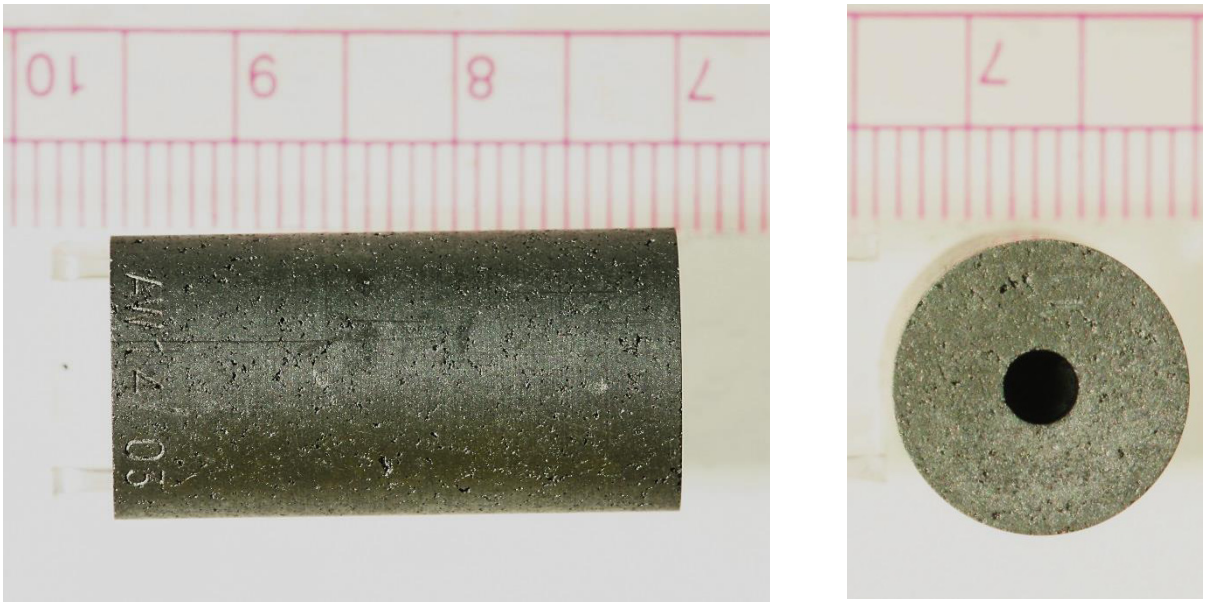


Figure 12. Prost irradiation visual inspection images for sample AW14 03.

Once the specimen has been inspected and photographed it is placed in a snap cap plastic container that is barcode labeled with the corresponding specimen number (Figure 13). These bar codes are used to track the specimen throughout all post characterization activities and measurements. Initially it is used by a semiautomatic storage location data base. Using INL-developed software, the bar code is read and the next available storage location is identified in the shielded storage vault (Figure 14). As specimens are needed for post irradiation characterization, the desired specimen number is entered into the software and its storage location is identified for retrieval. Appendix A contains a listing of all AGC-2 specimens retrieved from the experiment capsule and there storage vault location. All digital photographs will be stored along with the results from thermal, mechanical, and physical testing with project files, becoming part of the permanent record for each individual sample.

Figure 13. Example of plastic snap cap container used to hold individual specimens.

Figure 14. Shielded storage vault. Each platter is independently rotated to minimize direct radiation exposure from multiple specimens.

Appendix A

Specimen Inventory

Specimen			Location
Number A	Number B	Number C	
DW16 03			A-V-1-A
FW08 02			A-V-2-B
CW13 03			A-V-3-A
AW17 10			A-V-3-C
FW06 03			A-V-4-B
EW08 01			A-V-5-A
EW06 03			A-V-5-D
BW3 01			A-V-6-B
FW08 01			A-V-7-A
DW16 02			A-V-7-C
AW13 01			A-V-8-B
AW12 01			A-V-9-A
BW15 03			A-V-9-D
BW2 03			A-V-10-B
CW3 02			A-V-11-A
EW07 04			A-V-11-C
BP6 01			A-V-12-B
DA6 01			A-V-13-A
AP5 01			A-V-13-D
AW17 07	TP27		A-V-14-B
AW1 03			A-V-15-A
CW12 02			A-V-15-C
BP4 02			A-V-16-B
EW01 02			A-V-17-A
FW01 01			A-V-17-D
BW1 02			A-V-18-B
BW13 02			A-V-19-A
FW04 01			A-V-19-C
DW12 03			A-V-20-B
EW04 03			A-V-21-A
EW03 01			A-V-21-D
BW11 03			A-V-22-B
BW1 01			A-V-23-A

Specimen			Location
Number A	Number B	Number C	
DW11 03			A-V-23-C
BW13 01			A-V-24-B
EW03 02			A-V-25-A
DW1 02			A-V-25-D
DA4 02			A-V-26-B
CW1 01			A-V-27-A
DW12 04			A-V-27-C
FW03 01			A-V-28-B
DW1 01			A-V-29-A
CW11 01			A-V-29-D
A3-P33-Z09			A-V-30-B
CW10 03			A-V-31-A
BW12 01			A-V-31-C
DA4 03			A-V-32-B
FW03 02			A-V-33-A
DW11 04			A-V-33-D
EW03 03			A-V-34-B
AP4 02			A-V-35-A
BP4 03			A-V-35-C
AW10 01			A-V-36-B
S1 07	L1 07		A-V-37-A
K1 08	EW15 02		A-VI-1-A
P1-08	CPB71		A-VI-2-B
M1 09	BW17 09		A-VI-3-A
J1 07	DA8 02		A-VI-3-C
TP08	S1 08		A-VI-4-B
EW15 01	RW1 09		A-VI-5-A
FW16 01	P1-07		A-VI-5-D
RW1 08	L1 08		A-VI-6-B
CPB61	TP07		A-VI-7-A
J1 08	M1-08		A-VI-7-C
DA8 03	CW14 03		A-VI-8-B
K1 09	CPB151		A-VI-9-A
H512	AP7 10		A-VI-9-D
AW17 08	BW17 08		A-VI-10-B
L2 08	DW18 03		A-VI-11-A
L3 03	S2 12		A-VI-11-C

Specimen			Location
Number A	Number B	Number C	
K2 09	J2 06		A-VI-12-B
K3 06	FW15 01		A-VI-13-A
P3-04	EW14 06		A-VI-13-D
EW14 01	RW2 09		A-VI-14-B
J2 11	CW14 06		A-VI-15-A
TP18	H591		A-VI-15-C
BP7 06	RW4 04		A-VI-16-B
K3 04	TP15		A-VI-17-A
M2-07	M2-12		A-VI-17-D
P3-03	TP23		A-VI-18-B
P2-08	S2 07		A-VI-19-A
H562			A-VI-19-C
EW10 02			A-VI-20-B
BP3 01			A-VI-21-A
DA2 02			A-VI-21-D
DW2 04			A-VI-22-B
EW02 04			A-VI-23-A
FW10 02			A-VI-23-C
DW11 01			A-VI-24-B
BW11 02			A-VI-25-A
AW14 03			A-VI-25-D
DW11 02			A-VI-26-B
EW10 01			A-VI-27-A
FW02 04			A-VI-27-C
CW10 02			A-VI-28-B
BW11 01			A-VI-29-A
SPACER DW2 04	SPACER EW10 01		A-VI-29-D
SPACER DW11 01			A-VI-30-B
A3-H08-Z19			A-VI-31-A
A3-P33-Z20			A-VI-31-C
A3-P43-Z12			A-VI-32-B
	EW14 04		A-VI-33-A
CPB21	CPB101		A-VI-33-D
DW18 08	J1 01		A-VI-34-B
J1 10	CW14 05		A-VI-35-A
S1 02	L1 03		A-VI-35-C

Specimen			Location
Number A	Number B	Number C	
CPB91	S1 03		A-VI-36-B
P1-02	RW1 04		A-VI-37-A
H472	M1-11		A-VII-1-A
L1 01	BP7 08		A-VII-2-B
L2 01	EW14 09		A-VII-3-A
RW1 02	TP10		A-VII-3-C
DA8 05	FW15 07		A-VII-4-B
RW2 02	BP7 09		A-VII-5-A
M1-12	K2 01		A-VII-5-D
P2-01	K1 01		A-VII-6-B
P1-10	AW17 04		A-VII-7-A
AW17 05	M1-04		A-VII-7-C
EW14 08	CPB1		A-VII-8-B
RW2 01	K1 03		A-VII-9-A
K2 02	BW17 03		A-VII-9-D
TP01	FW15 04		A-VII-10-B
DW18 10	TP03		A-VII-11-A
M1-01	CPB11		A-VII-11-C
RW1 03	TP11		A-VII-12-B
H482	BW17 02		A-VII-13-A
S1 10	J1 03		A-VII-13-D
FW15 09	TP02		A-VII-14-B
K1 04	M1-02		A-VII-15-A
P1-03	L1 02		A-VII-15-C
J1 11	CA11 02		A-VII-16-B
CPB111			A-VII-17-A
CA11 01	DW18 09		A-VII-17-D
EW14 07	L1 10		A-VII-18-B
S1 11	J1 02		A-VII-19-A
BP7 10	AW17 06		A-VII-19-C
FW15 08			A-VII-20-B
EW09 01			A-VII-21-A
DA5 03			A-VII-21-D
DW2 01			A-VII-22-B
FW07 03			A-VII-23-A
FW06 02			A-VII-23-C
DA3 03			A-VII-24-B

Specimen			Location
Number A	Number B	Number C	
FW09 03			A-VII-25-A
CW3 01			A-VII-25-D
AW13 03			A-VII-26-B
AW11 03			A-VII-27-A
DW14 03			A-VII-27-C
DW16 01			A-VII-28-B
EW07 03			A-VII-29-A
EW06 02			A-VII-29-D
BW2 01			A-VII-30-B
EW06 01			A-VII-31-A
BW2 02			A-VII-31-C
EW09 02			A-VII-32-B
BP5 03			A-VII-33-A
BP4 01			A-VII-33-D
DW15 04			A-VII-34-B
TP16	EW15 11		A-VII-35-A
DW2 03			A-VII-35-C
FW03 03			A-VII-36-B
DW10 03			A-VII-37-A
AW1 02			A-VIII-1-A
CW5 01			A-VIII-2-B
CW1 03			A-VIII-3-A
FW10 01			A-VIII-3-C
EW02 02			A-VIII-4-B
FW02 01			A-VIII-5-A
BW5 02			A-VIII-5-D
BW10 02			A-VIII-6-B
A3-H08-Z07			A-VIII-7-A
AP6 01			A-VIII-7-C
BP5 01			A-VIII-8-B
A3-P43-Z03			A-VIII-9-A
L1 06	AP7 08		A-VIII-9-D
TP06	DA8 04		A-VIII-10-B
FW15 11	CPB51		A-VIII-11-A
M1-07	TP13		A-VIII-11-C
CPB141	P1-09		A-VIII-12-B
CPB81	K1 10		A-VIII-13-A

Specimen			Location
Number A	Number B	Number C	
H521	S1 06		A-VIII-13-D
DA8 01	EW15 03		A-VIII-14-B
BW17 07	K1 07		A-VIII-15-A
RW1 10	J1 05		A-VIII-15-C
BW17 01	EW14 11		A-VIII-16-B
CW14 04	TP09		A-VIII-17-A
K1 06	M1-10		A-VIII-17-D
AP7 09	L1 09		A-VIII-18-B
AW17 02	J1 09		A-VIII-19-A
FW15 12	S1 09		A-VIII-19-C
J1 06	CPB131		A-VIII-20-B
FW15 06	P1-06		A-VIII-21-A
EW14 12	RW1 07		A-VIII-21-D
FW15 05			A-VIII-22-B
BW13 03			A-VIII-23-A
EW06 04			A-VIII-23-C
FW05 01			A-VIII-24-B
EW04 04			A-VIII-25-A
BW14 01			A-VIII-25-D
DW13 01			A-VIII-26-B
BW14 03			A-VIII-27-A
FW05 03			A-VIII-27-C
DW14 04			A-VIII-28-B
EW05 01			A-VIII-29-A
DA6 02			A-VIII-29-D
DW13 02			A-VIII-30-B
AW12 02			A-VIII-31-A
BW16 01			A-VIII-31-C
AW11 01			A-VIII-32-B
CW12 03			A-VIII-33-A
FW04 04			A-VIII-33-D
TP12			A-VIII-34-B
DA5 01			A-VIII-35-A
CW2 01			A-VIII-35-C
CW1 02			A-VIII-36-B
BW1 03			A-VIII-37-A
BW10 01			B-I-1-A

Specimen			Location
Number A	Number B	Number C	
DW10 01			B-I-2-B
EA9 02			B-I-3-A
AW14 01			B-I-3-C
AW1 01			B-I-4-B
DW10 02			B-I-5-A
DA3 02			B-I-5-D
DW2 02			B-I-6-B
BW5 01			B-I-7-A
CW4 02			B-I-7-C
FW01 04			B-I-8-B
EW01 04			B-I-9-A
EW02 01			B-I-9-D
FW09 04			B-I-10-B
BP3 03			B-I-11-A
CW4 03			B-I-11-C
AP5 03			B-I-12-B
FW01 03			B-I-13-A
TP17			B-I-13-D
BP6 02			B-I-14-B
BW12 02			B-I-15-A
DW16 04			B-I-15-C
BW16 02			B-I-16-B
EW08 02			B-I-17-A
DW12 01			B-I-17-D
DW13 03			B-I-18-B
BW14 02			B-I-19-A
FW05 02			B-I-19-C
CW2 02			B-I-20-B
BW3 02			B-I-21-A
AW11 02			B-I-21-D
CW13 01			B-I-22-B
AP5 02			B-I-23-A
AW13 02			B-I-23-C
CW3 03			B-I-24-B
FW08 03			B-I-25-A
AP4 03			B-I-25-D
FW06 04			B-I-26-B

Specimen			Location
Number A	Number B	Number C	
DW15 02			B-I-27-A
CW11 02			B-I-27-C
EW05 02			B-I-28-B
EW15 08	AW17 09		B-I-29-A
AW17 01	TP24		B-I-29-D
EW05 04			B-I-30-B
DW12 02			B-I-31-A
BW15 01			B-I-31-C
FW03 04			B-I-32-B
BW15 02			B-I-33-A
EW04 01			B-I-33-D
DW14 02			B-I-34-B
EW04 02			B-I-35-A
AW10 03			B-I-35-C
DW14 01			B-I-36-B
BP5 02			B-I-37-A
CW13 02			B-II-1-A
FW06 01			B-II-2-B
FW05 04			B-II-3-A
DA5 02			B-II-3-C
TP19	EW14 03		B-II-4-B
S2 09	BP7 07		B-II-5-A
EW14 02	FW15 02		B-II-5-D
P2-09	H572		B-II-6-B
M2-09	DW18 05		B-II-7-A
EW15 10	RW2 10		B-II-7-C
TP20	K2 10		B-II-8-B
H571	J2 07		B-II-9-A
DW18 04	J2 08		B-II-9-D
RW4 01	L2 09		B-II-10-B
FW15 03	TP26		B-II-11-A
P2-10	L2 10		B-II-11-C
M2-08	L3 04		B-II-12-B
K3 01	S2 08		B-II-13-A
BW4 02			B-II-13-D
FW07 01			B-II-14-B
EW07 02			B-II-15-A

Specimen			Location
Number A	Number B	Number C	
EW07 01			B-II-15-C
CW4 01			B-II-16-B
FW09 02			B-II-17-A
DA7 01			B-II-17-D
EW08 04			B-II-18-B
DW15 03			B-II-19-A
BP6 03			B-II-19-C
DW17 02			B-II-20-B
DW17 04			B-II-21-A
AW12 03			B-II-21-D
BW4 01			B-II-22-B
L3 05	P3-01		B-II-23-A
P3-02	P3-05		B-II-23-C
H581	J2 09		B-II-24-B
K3 02	RW4 03		B-II-25-A
DW18 06	S2 10		B-II-25-D
K3 03	RW4 02		B-II-26-B
DW18 07	K3 05		B-II-27-A
EW14 05	H582		B-II-27-C
L3 02	TP22		B-II-28-B
M2-10	EW15 06		B-II-29-A
L3 06	S2 11		B-II-29-D
P3-06	J2 10		B-II-30-B
M2-11	TP21		B-II-31-A
L3 01			B-II-31-C
BW17 05	J1 04		B-II-32-B
BW5 03			B-II-33-A
FW08 04			B-II-33-D
FW02 03			B-II-34-B
EW02 03			B-II-35-A
FW02 02			B-II-35-C
CW11 03			B-II-36-B
BW12 03			B-II-37-A
FW09 01			B-III-1-A
CW5 03			B-III-2-B
DW17 01			B-III-3-A
EW03 04			B-III-3-C

Specimen			Location
Number A	Number B	Number C	
CW2 03			B-III-4-B
DW13 04			B-III-5-A
DA2 03			B-III-5-D
S1 05	RW1 06		B-III-6-B
AW17 03	FW15 10		B-III-7-A
H491	K1 05		B-III-7-C
CPB121	EW14 10		B-III-8-B
L1 04	DW18 12		B-III-9-A
CPB41			B-III-9-D
FW01 02			B-III-10-B
BP3 02			B-III-11-A
FW07 04			B-III-11-C
BW16 03			B-III-12-B
BW4 03			B-III-13-A
FW04 02			B-III-13-D
EW08 03			B-III-14-B
EW05 03			B-III-15-A
L1 05	TP25		B-III-15-C
P1-01	EW15 07		B-III-16-B
P1-05	TP05		B-III-17-A
TP14	DW18 11		B-III-17-D
CPB31	BW17 04		B-III-18-B
RW1 05	AL14 03		B-III-19-A
EW15 09	AL14 02		B-III-19-C
M1-06	TP04		B-III-20-B
S1 04	P1-04		B-III-21-A
EW09 04			B-III-21-D
BW3 03			B-III-22-B
DW10 04			B-III-23-A
BW10 03			B-III-23-C
AW10 02			B-III-24-B
AW14 02			B-III-25-A

Appendix B

AGC-2 Disassembly Activity Log

10 February

Moved test train to the disassembly table, set down, and installed pipe cutter without incident. Made first cut on bottom. Separated beautifully.

Unable to push graphite body out of stainless pressure boundary tube. Concluded that it was stuck just above where the cap was cut off. Started new cut ~1 inch above bottom cut. Had problem retracting one of the two cutting tools. Ran cutter with one tool until the unit stuck. Assume cutter pulled up too big of a chip and could not clear it. Got test train out of cutter and moved off the table to work on replacing/repositioning cutter(s). Got one repositioned. Tried to retract other with no success. Will try to get sketches to help figure out problem.

11 February

The second cut performed on 10 Feb 2014 resulted in the pipe cutter coming to a stop when it had completed approximately 30% of the desired cut. That cut was being done with a single cutter because the feed starwheel for the other cutter was not retracting the holder. The rotary pipe cutter has two parting tools in this configuration that are driven by a planetary gear. The cutter was removed and the remaining cutter was used to attempt a cut approximately 1-1/4 inches closer to the top of the test train than the initial cut. It was not clear whether the cutter dulled to the point that it was not cutting cleanly enough for the air drive to overcome the friction, or whether some degree of work-hardening of the irradiated steel occurred due to the rate the cutter was being operated. After review of the pipe cutter manual, it appeared that the feed nut threads on the one non-advancing/retracting feed component may have been stripped, resulting in its refusal to move.

The pipe cutter unit was removed from the disassembly table rail and moved to Window 10M where the light is better and there is more room to work. The cutter feed component was removed from the unit, and the threads on the feed screw and nut inspected, with the conclusion that they were not stripped. The cutter was reassembled and fitted with a new parting tool, and repositioned on the disassembly table rail.

Because the previous cuts were made with the carriage rail clamps in a partially raised position, the test train had been positioned in the pipe tipped slightly with the end in the cutter being lower than the end in the carriage rail clamps. The depth of the test train in the clamps is controlled by adjusting a screw that drives two V-blocks. To level the test train, the V-blocks in the clamps were lowered to their bottom orientation.

The collet was tightened down on the test train following clamp adjustment with the cut approximately 1/2 inch above the previous unsuccessful cut, and the parting tools adjusted to contact the tube, then backed off one turn for the tool with the new edge, and 1-1/2 turns for the used tool.

The first rotation of the tool indicated that the collet was not sufficient to hold the test train securely, so the carriage clamps were tightened down using the split-top clamps.

The cut then proceeded with good curls, indicating a sharp tool and consistent rotation speed that was not causing work-hardening. The cut proceeded to completion as determined by visible graphite on the side facing the window. Approximately four additional rotations were required to complete the cut on the far side of the tube, indicating a slight off-center positioning in the collet. Rotation was stopped when the cut piece began to rotate with the tool. The graphite body inside appears to be one unit, since the top end could be seen to move inside the steel tube at the same time as the cut end.

The pipe cutter tools were retracted, the collet released and the pipe cutter removed from the rail. Note that the starwheel drives, are definitely left-threaded, so that retraction is clockwise rotation. It is clear that the drive that refused to move on the previous day had simply been turned to the point that the starwheel feed screw became separated from the feed nut.

The decision was made to manually separate the steel tube from the graphite body by sliding it laterally. To avoid interference with the leadscrew drive that is located on the right side of the disassembly table, the test train was rotated to be positioned with the cut at the right side of the table so that the tube could be slid to the open space on the right side for removal. The tube was moved away from the cut approximately 3 inches. The resistance was enough to result in the decision to use the leadscrew drive and the carriage clamps to overcome the primary resistance. That step was deferred until the next day due to the time of the shift.

12 February

Started at 1330 due to operator training. The steel cap was clamped into the right clamp of the leadscrew driven carriage, and the left carriage was locked at the far left end of the rail with the steel pressure boundary tube clamped in its middle clamp. The lifting bail cap installed on the left (top) end of the tube to ensure that no samples fell out during the linear pull to separate the graphite body from the steel tube. Approximately 2 inches of graphite was exposed at this starting point.

The pull proceeded with approximately 6 inches being extracted from the tube with minimal indication of friction. The clamp on the left carriage was loosened and the tube was raised slightly to allow the offset nubs on the outside of the tube to pass through the left clamp of the right carriage. The right carriage was then driven to the extent of its travel to the right. The small pneumatic ratchet drive was used on the 10:1 reduction gear to move the right carriage to the right. The right side clamp on the right carriage was released, and the carriage repositioned to continue the separation pull. A crack in the graphite at the point where the steel cap and the graphite join, indicating that the graphite end cap was being pulled away from the graphite body. The gas lines were still in place, retaining all of the samples. The right-hand clamp was moved from the steel cap to the graphite body and the lateral pull on the graphite was continued. The body moved smoothly for approximately another 4 inches, at which point the lower graphite body joint was visible, and the joint began to separate.

Seeing the section begin to separate led to the decision to remove the lower section from the main disassembly table to the sorting table and push out the samples into shipping tubes so as to limit the possibility of contamination or loss of samples. The steel cap and the gas lines were manually removed, which involved pulling back all of the gas lines and pulling off the cap. Several of the piggyback samples fell out of the cap as part of the separation effort. A catch tray was staged under the cap prior to separation, and the piggyback samples were poured out of the cap into the tray. Two piggyback samples were observed to have fallen out during the effort, and were retrieved and placed in the tray.

The graphite body section was then manually lifted with the master-slave manipulator and transferred to the radial position insert of the sorting table. A receiving tube was mounted onto the receiving end of the sorting table tray. One of the piggyback samples fell out of the body and sat in the path of the pushrod, so it was removed with tweezers. The pushrod was advanced to the right to confirm that the samples could be pushed out with only manual force. The samples were observed to move smoothly. Due to having reached the end of the shift, the samples and equipment were covered with plastic bags and secured for the day.

The next task will be to complete the pushout of samples from the bottom graphite body section, then reposition the steel pressure tube for another cut to expose the remainder of the graphite body for removal.

13 February

Performed separation and transfer of full-size and piggyback samples from the first two radial positions in the bottom 1-foot-long section of the graphite body. Flux wire spacers were removed from two positions, and the flux wires removed from the spacers and placed in small poly cryo-vials.

17 February

Continued separation and transfer of radial samples from the remaining four radial positions in the bottom 1-foot section of the graphite body. Removed three flux wire spacers and separated the flux wires without incident. Encountered a flux wire spacer in which the flux wire was stuck, requiring fabrication of a tool to penetrate the hole in the spacer. Recommended that unless the flux wire spacer cannot be separated from the primary sample, the spacer should be set aside and the flux wire removed at a later time, so as to speed up transfer of primary samples. All remaining flux wire spacers were placed in 30-ml poly bottles for later separation.

Completed removal of center stack piggyback samples from bottom 1-foot section. It appears that one of the HOPG sample containers came open and the cup component has not been located. Transferred graphite body into poly container for dimensional checks following all sample removal.

Will work on another cut of the steel pressure boundary tube to expose another section of the graphite body for sample removal.

18 February

Because it appeared that the graphite body was at a point where the steel boundary tube interfered with either pulling or pushing out the graphite, a cut approximately 6 inches from the bottom end of the tube was made. The cut required some intermediate adjustment of the cutter as it had a tendency to reach a point where the chip would create sufficient friction to rotate the workpiece in the collet. After two adjustments of the carriage clamps and the collet, and use of intermittently advancing the cutter to ensure that the chip was broken off prior to continuing the cut, the separation was completed. When the cutter broke through the steel tube, the cut end rotated with the cutter, and following a lateral pull with the manipulator, the lower end thermocouples pulled out with a cut section of graphite inside the freshly cut off steel tube section. The cut end of the graphite showed no sign of irregular shear marks, and appeared to have been cut, although the pipe cutter did not make contact with the graphite. The point of separation coincided with the ends of the samples inside the graphite body, so no full-sized samples fell out of either section of the graphite. One piggyback center stack sample fell out and was retrieved.

This left the steel tube with one graphite section visible on the end where the cut had been most recently done, and the other end with a graphite body that had slid back into the tube approximately 3 inches.

A large diameter pushplug was installed on the left hand rail bracket, and the fresh cut end was pushed into the tube with the expectation that the other end of the graphite body would protrude from the right side of the steel boundary tube. The 6-inch-long tube progressed its full length and no graphite was pushed out the other end. Apparently, the lower two sections of graphite body had separated during the initial pull-apart step, leaving a gap between the sections inside the tube. A large deep socket was inserted into the tube between the graphite body and the large pushplug, and the carriage was moved to the left to push out. The result was that one of the 12-inch sections protruded from the right and was retrieved with manipulator and moved to the sorting table.

19 February

The samples in the section removed at the end of the day on Tuesday 18 Feb were pushed out, identified and placed in transport tubes.

Three 6-inch pushplug extensions were fabricated and transferred into the cell. The extensions were inserted into the main steel tube sequentially. That is, the main large push plug was advanced to its limit, retracted, another pushplug extension was inserted, and the carriage moved to push against the graphite body. Two extensions were inserted, and the result was that the thin steel shim stock heat shield began to push out with the graphite body.

After pushing out approximately 24 inches of the heatshield, the steel boundary tube was lifted and pulled off of the heatshield and graphite body section that remained. The seam on the heat shield was identified, and the shim stock heatshield tube peeled apart using tweezers to expose the graphite body section. The heatshield separated and tore away from the graphite except for the upper 10 inches where it appeared that the multiple spotwelds that hold the material in a tube prevented the graphite from being easily pulled away. Use of the tweezer tips and a small scriber in the gas line slots made a tear in the heatshield so that it could be completely removed.

The remaining graphite body included the middle joint, and that joint was separated by use of careful rotating and twisting of the two pieces with the manipulators. Care was exercised to assure that no samples were lost from the graphite body during this step. The small section was placed on the sorting table, and made ready for the next day's sample sorting.

20 February

Pushed out all samples from lower part of upper section of the graphite body. Separated flux wires. Marked section to allow identification at later date. Covered up experiment for day. Final 6-inch section will need to be removed from stainless steel tube and samples rodded out. Afternoon facility personnel training, no support. Expect to have support Monday.

25 February

Used a combination of push plugs held with manipulator and mounted on the end bracket of the leadscrew drive to push the final section from the stainless steel tube. Some of the center stack piggyback samples had been displaced from the center channel. Those items were removed from the tube prior to pushout to avoid dropping them during the pushout. Once the initial push exposed the graphite body, a manipulator was used to pull it the remainder of the way from the tube and place it in the tray on the sorting table. The end that separated apparently cleanly as a result of the pipe cutter operation of 18 Feb is somewhat beveled, suggesting a less than perfect break than previously indicated. Individual samples were then pushed out into the transport tubes.

4 March

Having emptied the graphite bodies, dimensional measurements were made. The various sections were placed on the sorting table tray and the Vernier caliper was used to check each section's length. The sections were measured at three different points, rotating 120 degrees between measurements. The caliper operation was consistent, allowing the pieces to be held in a good orientation, but the results were inconsistent, in that the measurements at several points were not repeatable. This suggests that the process of separating the sections deforms the joint in a way that makes definitive measurements problematic.

6 March

Transport tubes surveyed and loaded out from the HFEF Glove wall and placed in the shielded shipping drum. Maximum individual tube dose rate report as 200 mR/hr.

13 March

The graphite body measurements were continued, using the same micrometer used for AGC-1 to determine variations in graphite body OD. As with the overall length measurements, the OD was checked at two different positions around the circumference. The boreholes were also measured using the bore gauge. To give an operational baseline, the bore gauge was inserted into a 0.516-inch inside diameter steel standard and the measurements in the graphite body were recorded as either a plus or minus value above or below the 0.516-inch ID standard. In general the results indicate that almost all channels are larger than the standard, while only two locations were noted as being smaller than the standard.

18 and 20 March

Removed flux wires from spacers and placed them in smaller Cryo-vials for easier shipping and direct gamma ray counting.

19 March

Shielded shipping drum loaded on truck and moved to IRC. IRC radcon and research staff notified prior to shipping, all surveys complete and truck out the MFC gate by approximately 1030.

Conclusions

The pipe cutter option produces considerably less loose chips that can be inadvertently transferred with the samples. It requires a large amount of effort to ensure that the collet is tight on the pipe. It made the first cut with the pressure boundary cocked at an angle because the individual clamps on the rail carriages were not at their lowest position. (Variable V-blocks can be used to raise or lower the pressure tube to align with different center points if doing pushout on the main disassembly rail.) The first cut had limited slippage of the tube, even at the end of the cut, presumably because of the friction of being clamped at an angle. In performing the second cut, one cutter was not retracted completely because it was not understood that the advance screw is left threaded. This meant that the unit needed to be disassembled and the advance screw restarted so that subsequent cuts could be made. The INL-designed- and fabricated- base that clamps the cutter to the rail uses two 1/4-20 bolts that became loose during the second cut, allowing it to vibrate when the uneven cutting was occurring. This component needs to be redesigned, either to allow the cutter to be self-adjusting with respect to the piece being cut, or to be more rigid to resist misalignment.

The sorting table is a significant improvement over the previous designs, having a minimal number of parts to operate, and being essentially self-centering. The pushrod does require some manual alignment to start into the radial channels if it is used with a short section, where the rod drops below optimal center because it is a larger distance from the support bushing. A support wedge could be fabricated to assist in this alignment. The self-adjusting De-Staco clamps used for holding the samples during separation of flux wire spaces do not apply as much force as might be ideal, presumably due to shrinkage of the sample OD. This can be overcome by applying force on the levers to clamp more tightly. A remote means to adjust the clamps would be ideal, but not an absolute requirement.

The graphite body length caliper appears to work well, and probably needs no modification. The micrometer used to measure graphite body ODs could be reworked, if only because it can only be read by using a mirror, and it works only with the main rail table. It may be fairly straightforward to produce a Vernier caliper that can be easily read when the graphite body is placed on the sorting table. The bore gauge was designed to work with the sorting table and required minimal effort to perform the measurements.

With regard to shipping, the process of using heat-sealed sleeving to ensure that the transport tubes are not contaminated appears to be effective. Use of the 6-mil urethane sleeving for primary covering for in-cell contamination versus the 2-mil polyethylene used in AGC-1 and 2 to reduce tearing of the sleeve during removal was recommended by the HFEF technicians.

Placing the flux wire spacers in 30-ml poly bottles prior to wire removal allows the wire to be separated by shaking the bottle rather than having to rod it out in the push-out funnel.

Appendix C

Graphite Body Measurements from HFEF Hot Cell

The terms used to refer to sections of the graphite body, also known as the "specimen holder," are derived from Sheet 3 of INL Drawing 630427. The Upper Section of the graphite body is noted at the bottom of the sheet as the -3 assembly, and the Lower Section is shown at the top of the sheet as the -2 assembly. For AGC-1 and -2, these assemblies were manufactured as nominal 12" long sections that are joined by a machined bayonet connector design. Because these sections were separated as a part of the sample removal process, they are referred to informally as "Upper-upper," meaning the top section of the top portion of the body, which corresponds to detail 8 on Sheet 3. Upper-lower is item 7, Lower-upper is item 6, and Lower-lower is item 5. The bayonet joint has a protruding section that engages a recessed section, referred to as male or female ends of the bayonet.

Measurements of the channel bores are noted as being at the top or bottom end of each section where the gauge was inserted. As an example from the Internal Channel Bore Measurements table, the first bore measurement is the diameter at 0.5 inch inside the Center channel bore on the bottom end of the lower part of the Lower Section:

Graphite Body Section :	Item 5 (Lower part of Lower Section)
End (Top/Bottom) :	Bottom (Male End)
Channel No. :	Center
Insertion depth (in.) :	0.5
Measured ID (± 0.516 in. standard) :	0.002
ID Total (in.) :	0.518

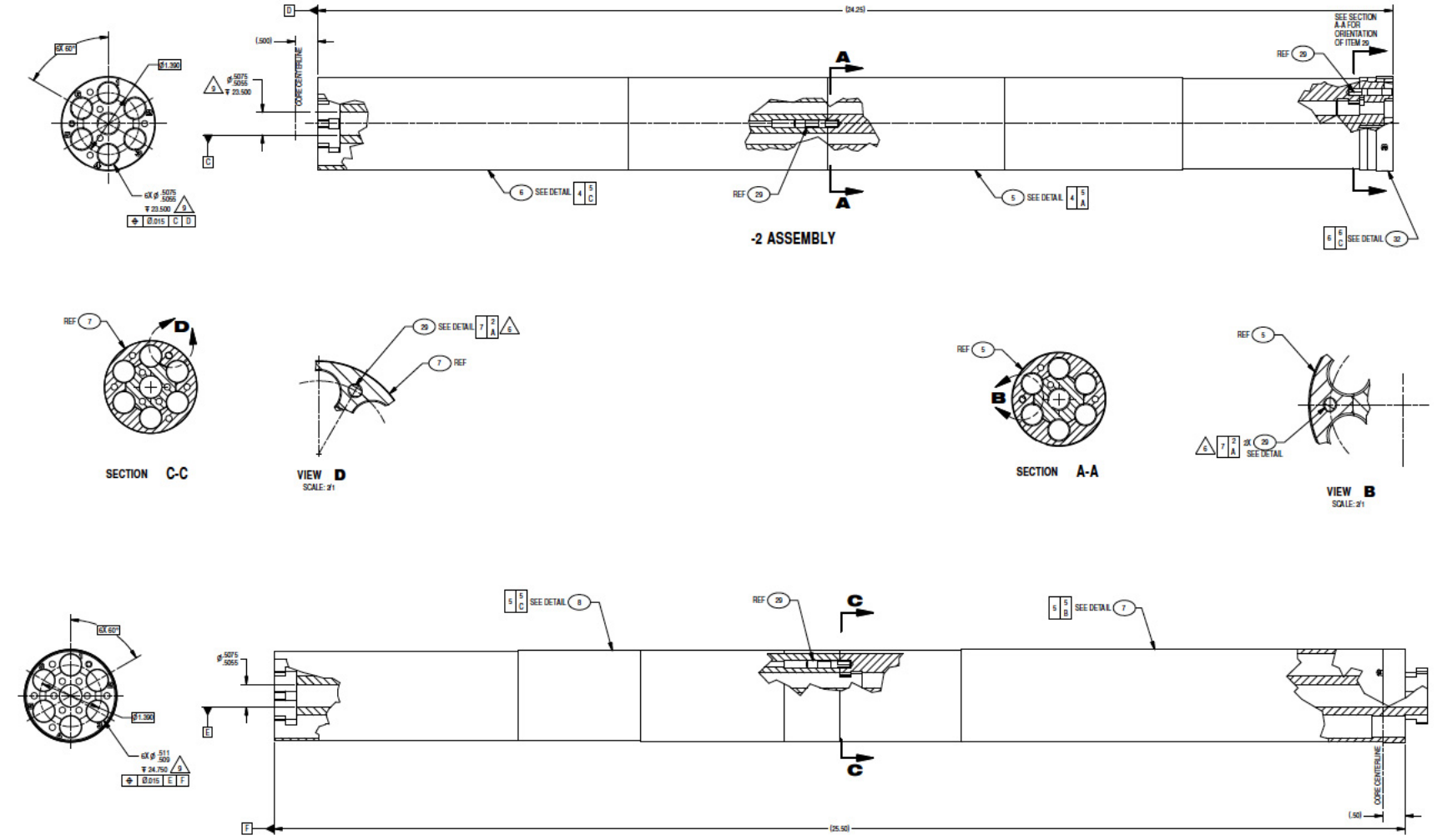


Figure C-1 Excerpt of Drawing 630427 AGC Specimen Holder and Insulator Details and Assemblies

Total Lengths of Graphite Body Sections

Graphite Body Section	Length (inches)
Upper Section (2 pieces locked together)	
at Channel 1	21.794
at Channel 3	21.79
at Channel 5	21.801
Average Length	21.795
Lower Section (3 pieces not absolutely aligned)	
at Channel 1	23.756
at Channel 3	23.707
at Channel 5	23.77
Average Length	23.744

Outer Graphite Body Diameter Measurements

Diameter	OD (in.)	Diameter	OD (in.)
Item 6 (Upper part of the Lower Section)		Item 8 (Upper part of the Upper Section)	
Female end	2.074	Upper section below step	2.06
90 degree rotated	2.074	90 degree rotated	2.059
Middle	2.078	Middle	2.054
90 degree rotated	2.081	90 degree rotated	2.059
Broken joint	2.079	Male end	2.055
90 degree rotated	2.081	90 degree rotated	2.054
Item 7 (bottom 12 inches of Upper Section)			
3 inches from centerline	2.069		
90 degree rotated	2.075		
6 inches from centerline	2.075		
90 degree rotated	2.072		
9 inches from centerline	2.069		
90 degree rotated	2.072		
Upper end (female)	2.073		
90 degree rotated	2.072		
Male end	2.068		
90 degree rotated	2.073		

Internal Channel Bore Measurements

Graphite Body Section	End (Top/Bottom)	Channel No.	Insertion Depth (in.)	Measured ID (± 0.516 in. standard)	ID Total (in.)
Item 5 (Lower part of Lower Section)					
	Bottom (Male End)	Center	0.5	0.002	0.518
			1	0.002	0.518
			1.5	0.002	0.518
		1	0.5	0.01	0.526
			1	0.009	0.525
			1.5	0.0095	0.5255
		2	0.5	0.0095	0.5255
			1	0.0085	0.5245
			1.5	0.008	0.524
		3	0.5	0.0125	0.5285
			1	0.0115	0.5275
			1.5	0.0105	0.5265
		4	0.5	0.0115	0.519
			1	0.0115	0.519
			1.5	0.0115	0.519
		5	0.5	0.015	0.531
			1	0.0135	0.5295
			1.5	0.013	0.529
		6	0.5	0.0165	0.5325
			1	0.011	0.527
			1.5	0.0105	0.5265
	Top (Female End)	Center	1	0.0005	0.5165
			1.5	0.0005	0.5165
		1	0.5	0.002	0.518
			1	0.002	0.518
			1.5	0.002	0.518
		2	0.5	0.0195	0.5355
			1	0.0195	0.5355
			1.5	0.0195	0.5355
		3	0.5	0.022	0.538
			1	0.0215	0.5375
			1.5	0.021	0.537
		4	0.5	0.0265	0.5425

Graphite Body Section	End (Top/Bottom)	Channel No.	Insertion Depth (in.)	Measured ID (± 0.516 in. standard)	ID Total (in.)
			1	0.0265	0.5425
			1.5	0.026	0.542
		5	0.5	0.021	0.537
			1	0.02	0.536
			1.5	0.02	0.536
		6	0.5	0.022	0.538
			1	0.022	0.538
			1.5	0.023	0.539
Item 6 (Lower part of Upper Section)					
Upper Part of Broken Item 6	Top (Female End)	Center	0.5	0.001	0.5175
			1	0.0005	0.517
		1	0.5	0.0025	0.5185
			1.0	0.0025	0.5185
			1.5	0.0025	0.5185
		2	0.5	-0.001	0.515
			1.0	0.0005	0.5165
			1.5	0.0005	0.5165
		3	0.5	0.0015	0.5175
			1.0	0.0015	0.5175
			1.5	0.0015	0.5175
		4	0.5	0.003	0.519
			1.0	0.003	0.519
			1.5	0.003	0.519
		5	0.5	0.0015	0.5175
			1.0	0.003	0.519
			1.5	0.003	0.519
		6	0.5	0.002	0.518
			1.0	0.002	0.518
			1.5	0.0025	0.5185
	Bottom (Male End)	Center	0.5	0.0045	0.5205
			1.0	0.0035	0.5195
			1.5	0.002	0.518

Graphite Body Section	End (Top/Bottom)	Channel No.	Insertion Depth (in.)	Measured ID (± 0.516 in. standard)	ID Total (in.)
Lower Part of Broken Item 6	Top	Center	0.5	0.001	0.517
			1.0	0.0005	0.5165
			1.5	0.0005	0.5165
		Center	0.5	0.0005	0.5165
			1.0	0.0005	0.5165
			1.5	0.0005	0.5165
	Bottom	1	0.5	0.001	0.517
			1.0	0.001	0.517
			1.5	0.001	0.517
		2	0.5	0.001	0.517
			1.0	0.001	0.517
			1.5	0.001	0.517
		3	0.5	0.003	0.519
			1.0	0.002	0.518
			1.5	0.0005	0.5165
		4	0.5	0.0005	0.5165
			1.0	0.001	0.517
			1.5	0.0015	0.5175
		5	0.5	0.0005	0.5165
			1.0	0.0005	0.5165
			1.5	0.0005	0.5165
		6	0.5	-0.0101	0.5059
			1.0	-0.0005	0.5155
			1.5	-0.0005	0.5155
Item 7 (Upper part of Lower Section)					
	Top	1	0.5	0.0255	0.5415
			1.0	0.0255	0.5415
			1.5	0.0255	0.5415
		2	0.5	0.0255	0.5415
			1.0	0.0255	0.5415
			1.5	0.0255	0.5415
		3	0.5	0.022	0.538
			1.0	0.022	0.538
			1.5	0.022	0.538
		4	0.5	0.022	0.538
			1.0	0.022	0.538
			1.5	0.022	0.538

Graphite Body Section	End (Top/Bottom)	Channel No.	Insertion Depth (in.)	Measured ID (± 0.516 in. standard)	ID Total (in.)
		5	0.5	0.0295	0.5455
			1.0	0.0295	0.5455
			1.5	0.0295	0.5455
		6	0.5	0.025	0.541
			1.0	0.0255	0.5415
			1.5	0.0255	0.5415
	Bottom (Female End)	Center	1.0	-0.002	0.514
			1.5	-0.002	0.514
		1	0.5	0.035	0.551
			1.0	0.035	0.551
			1.5	0.035	0.551
		2	0.5	0.034	0.55
			1.0	0.0345	0.5505
			1.5	0.0345	0.5505
		3	0.5	0.0345	0.5505
			1.0	0.0345	0.5505
			1.5	0.0345	0.5505
		4	0.5	0.0345	0.5505
			1.0	0.035	0.551
			1.5	0.0355	0.5515
		5	0.5	0.029	0.545
			1.0	0.029	0.545
			1.5	0.029	0.545
		6	0.5	0.0355	0.5515
			1.0	0.0375	0.5535
			1.5	0.0375	0.5535
Item 8 (Upper part of Upper Section)					
		Center	0.5	0.0035	0.5195
			1.0	0.0035	0.5195
			1.5	0.0035	0.5195
		1	0.5	0.37	0.886
			1.0	0.365	0.881
			1.5	0.365	0.881
	Top	2	0.5	0.03	0.546
			1.0	0.032	0.548
			1.5	0.032	0.548

Graphite Body Section	End (Top/Bottom)	Channel No.	Insertion Depth (in.)	Measured ID (± 0.516 in. standard)	ID Total (in.)
		3	0.5	0.037	0.553
			1.0	0.037	0.553
			1.5	0.0375	0.5535
		4	0.5	0.037	0.553
			1.0	0.037	0.553
			1.5	0.037	0.553
		5	0.5	0.036	0.552
			1.0	0.0355	0.5515
			1.5	0.036	0.552
		6	0.5	0.0365	0.5525
			1.0	0.037	0.553
			1.5	0.0375	0.5535
	Bottom	Center	0.5	-0.002	0.514
			1.0	-0.002	0.514
			1.5	-0.002	0.514
		1	0.5	0.037	0.553
			1.0	0.037	0.553
			1.5	0.037	0.553
		2	0.5	0.037	0.553
			1.0	0.037	0.553
			1.5	0.037	0.553
		3	0.5	0.037	0.553
			1.0	0.037	0.553
			1.5	0.0375	0.5535
		4	0.5	0.037	0.553
			1.0	0.0375	0.5535
			1.5	0.0375	0.5535
		5	0.5	0.037	0.553
			1.0	0.037	0.553
			1.5	0.037	0.553
		6	0.5	0.037	0.553
			1.0	0.037	0.553
			1.5	0.037	0.553

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