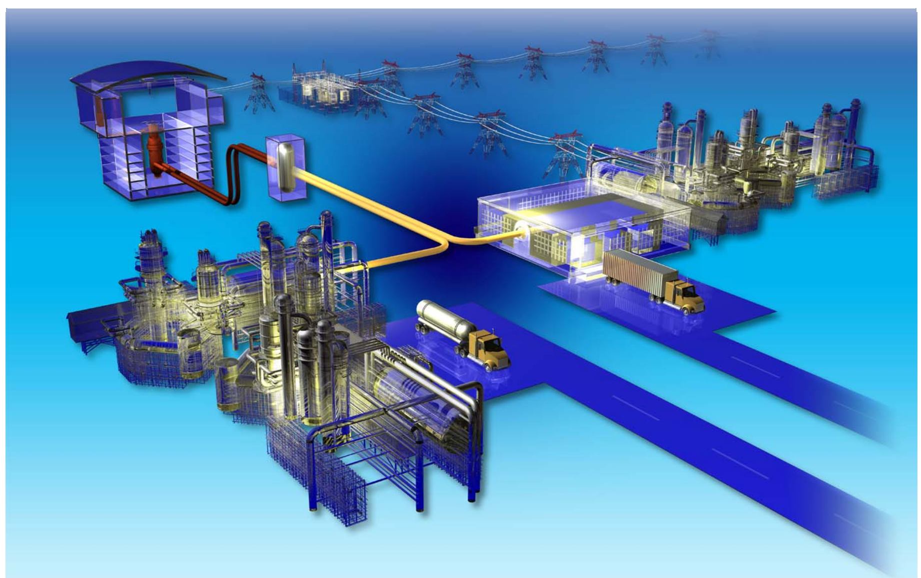
INL/EXT-09-15515

Carbon Characterization Laboratory Report

David Swank
William Windes
D.C. Haggard
David Rohrbaugh
Karen Moore

March 2009



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operated by Battelle Energy Alliance

Idaho National Laboratory

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Idaho National Laboratory
Next Generation Nuclear Plant Project
Idaho Falls, Idaho 83415

http://www.inl.gov

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Next Generation Nuclear Plant Project

Carbon Characterization Laboratory Report

INL/EXT-09-15515
Revision 0

March 2009

Approved by:

William Windes VHTR TDO Graphite R&D Lead	Date
Diane Croson VHTR TDO Project Manager	Date
Gary Roberts VHTR TDO Quality Assurance Lead	Date

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SUMMARY

The newly completed Idaho National Laboratory (INL) Carbon Characterization Laboratory (CCL) is located in Lab-C20 of the Idaho National Laboratory Research Center. This laboratory was established under the Next Generation Nuclear Plant (NGNP) Project to support graphite research and development activities. The CCL is designed to characterize and test carbon-based materials such as graphite, carbon-carbon composites, and silicon-carbide composite materials. The laboratory is fully prepared to measure material properties for nonirradiated carbon-based materials. Plans to establish the laboratory as a radiological facility within the next year are definitive. The laboratory will be modified to accommodate irradiated materials, after which it can be used to perform material property measurements on both irradiated and nonirradiated carbon-based material.

Instruments, fixtures, and methods are in place for preirradiation measurements of bulk density, thermal diffusivity, coefficient of thermal expansion, elastic modulus (Young’s modulus, Shear modulus, Poisson ratio), and electrical resistivity. The measurement protocol consists of functional validation, calibration, and automated data acquisition. Functional validations have been established for each measurement in collaboration with the instrument manufacturer and are performed periodically to verify the acquisition of accurate and consistent data. All validations are performed on traceable standards and documented in retrievable laboratory notebooks associated with each measurement. Calibration standards, methods, and frequencies have also been established for each measurement. Where it is not possible to use the INL Standards and Calibration Laboratory, calibration by user procedures are established based on American Society for Testing and Materials standards and manufacturer’s instructions and are performed against international standards. These procedures are documented in laboratory notebooks.

Significant improvements in specimen fixtures and data acquisition have been made specifically for preirradiation material property measurements in support of the Advanced Test Reactor Graphite Creep (AGC) experiment—a major material irradiation experiment within the NGNP Graphite program. These material property measurements are divided into individual measurement stations that consist of the instrumentation necessary to make the measurement, a computer for automated data acquisition, and a bar code reader. Each specimen is bar coded with its unique identity, and prior to each measurement, the specimen’s identity is automatically read and input. Automated data acquisition software has been written in LabVIEW for measurements of sonic velocity, fundamental frequency, electrical resistivity, and mass. This software takes the instrumentation output and interfaces it to Excel spreadsheets. This automated specimen identification and data acquisition eliminates data entry errors and significantly improves efficiency. The CCL is fully operational and ready to characterize the AGC-2 specimens before insertion into the irradiation capsule. As experience is gained using the equipment, improvements in measurement accuracy, precision, and method will be evaluated for possible improvements. If these changes are determined to be significant and beneficial, modification of the specific ASTM standard or measurement technique will be suggested.

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CONTENTS

FIGURES

TABLES

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Carbon Characterization Laboratory Report

1. INTRODUCTION

The Next Generation Nuclear Plant (NGNP) will be a helium cooled high temperature gas-cooled reactor (HTGR) with a large graphite core. The graphite, in the form of large blocks, physically contains the fuel and comprises the majority of the core volume. Graphite has been used effectively as a structural and moderator material in both research and commercial HTGRs. While the general characteristics necessary for producing nuclear grade graphite are understood, historical nuclear grades no longer exist. New grades must therefore be fabricated, characterized, and irradiated to demonstrate that current grades of graphite exhibit acceptable irradiated and nonirradiated properties upon which the thermo-mechanical design of the structural graphite in the NGNP is based. Further details on the research and development (R&D) activities and associated rationale needed to qualify nuclear grade graphite for use within the NGNP are documented.[1,2]

The newly completed Idaho National Laboratory (INL) Carbon Characterization Laboratory (CCL) is located in Lab-C20 of the INL Research Center. This laboratory was established under the NGNP Project to support graphite R&D activities. The CCL is designed to characterize and test carbon-based materials such as graphite, carbon-carbon composites, and silicon-carbide composite materials. Initial studies will focus on graphite in support of the NGNP project and will eventually test and characterize irradiated graphite samples after the CCL has been modified into a radiological facility. A preliminary design outlining the modifications necessary to achieve radiological status has been completed, and plans are in place to begin this work within 12 months.

Instruments, fixtures, and methods are currently in place for preirradiation material property measurements of bulk density, thermal diffusivity, coefficient of thermal expansion, elastic modulus (Young's modulus, Shear modulus, Poisson ratio), and electrical resistivity. Table 1 lists the instruments, material property measured, and American Society for Testing and Materials (ASTM) standard to which each measurement is performed. The measurement protocol consists of functional validation, calibration, and automated data acquisition. Functional validations have been established for each measurement in collaboration with the instrument manufacturer and are performed periodically to verify that accurate and consistent data is acquired. All validations are performed on traceable standards and documented in retrievable laboratory notebooks associated with each measurement. Calibration standards, methods, and frequencies have also been established for each measurement. Where it is not possible to use the INL Standards and Calibration Laboratory, calibration by user procedures are established that are based on ASTM standards and manufacturer's instructions, and performed against international standards. These procedures are documented in laboratory notebooks. An overall view of the CCL is shown in Figure 1.

Significant improvements in specimen fixtures and data acquisition have been made specifically to support Advanced Test Reactor Graphite Creep (AGC) sample measurements. The measurements listed in Table 1 are divided into individual measurement stations that consist of the instrumentation necessary to make the measurement, a computer for automated data acquisition, and a bar code reader. Each specimen is bar coded with a unique identity that is automatically read and input prior to each measurement. Automated data acquisition software has been written in LabVIEW for measuring sonic velocity, fundamental frequency, electrical resistivity, and mass. This software interfaces the instrumentation output with Excel spreadsheets. This automated specimen identification and data acquisition eliminates all data entry errors and significantly improves efficiency. The CCL is fully operational and ready to characterize the AGC-2 specimens. As experience is gained using the equipment, improvements in accuracy, precision, and efficiency will be made.

Table 1. CCL measurement and test equipment.

Measurement	Standard	Instrumentation	Calibration Method	Result
Physical dimensions	ASTM C559-05	Mitutoyo Micrometer 121-155 INL ID: 725884 Mitutoyo Caliper CD-6" CSX INL ID: 725813	INL Standards and Calibration Laboratory	Sample dimensions
Mass	ASTM C559-05	Sartorius Scale ME235P INL ID: 412642	INL Standards and Calibration Laboratory	Bulk density
Fundamental Frequency	ASTM C747-05 ASTM C1259-08	J. W. Lemmens Grindosonic INL ID: 412850	No calibration required per instrument manufacture.	Elastic modulus
Sonic velocity	ASTM C769-05	Olympus NDT Sq Wave Pulser/Receiver 5077PR Serial No: 080172402 National Instruments Digitizer USB 5133 Serial No: P10239379	INL Standards and Calibration Laboratory	Young's modulus, Shear modulus, Poisson ratio
4 point electrical resistivity	ASTM C611-05	Kiethly 6220 Precision Current Source INL ID: 725865 Kiethly 2182A Nano Voltmeter INL ID: 725866	INL Standards and Calibration Laboratory	Electrical resistivity
Laser flash diffusivity	ASTM E1461-01	Netzsch LFA 457 2ea. INL ID: 412855 INL ID: 412864	Calibration by user per manufactures instructions	Thermal diffusivity
Push rod dilatometry	ASTM E228-06	Netzsch KIL 402 C 2ea. INL ID: 412860 INL ID: 412861	Calibration by user per manufactures instructions	Coefficient of thermal expansion

Figure 1. Overall view of CCL.

This report summarizes the thermal and mechanical measurement techniques that will be used to characterize the different graphite types being tested in AGC experiments. Appendix A contains a detailed Quality Assessment of the CCL's readiness to perform Quality Level 2 measurements. As a final determination of the readiness of the laboratory, 10 representative graphite samples were measured and analyzed by the equipment within the CCL. The data obtained from these tests are summarized in a series of data tables in Appendix B.

2. FUNCTIONAL DESCRIPTION

Six different measurement stations are set up in the CCL to perform preirradiation characterization of AGC graphite: bulk density, thermal diffusivity, coefficient of thermal expansion, Young's modulus, Shear modulus, Poisson ratio, and electrical resistivity. Each station is equipped with measurement fixtures, instrumentation, a data acquisition computer, and a bar code reader. All instruments are networked to a server computer where the measurement data is stored, with the exception of data from thermal diffusivity and coefficient of thermal expansion measurements, which are collected by "off the shelf" instruments with manufacturer's software for automated data collection. All other measurements have been assembled by INL researchers with guidance from Oak Ridge National Laboratory and ASTM standards. Custom LabVIEW software was written to facilitate automated data acquisition. This software is comprised of five main programs: Manufacturers Data, Physical and Dimensional Measurements, Electrical Resistivity Measurements, Sonic Resonance (Fundamental Frequency) Measurements, and Sonic Velocity Measurements. These five programs acquire data from instrumentation or user input and record the results in an Excel spreadsheet that is located on the server computer. Below is a brief description of each of the programs and measurement techniques.

2.1 Manufacturer's Data

Before any measurements are made, specimen numbers and basic information about each type of graphite are entered using the manufacturer's data program. Its user interface is shown below in Figure 2. Once basic information about the graphite type has been entered, it is automatically saved to an Excel spreadsheet file and the individual specimen numbers are entered using a bar code reader as shown in Figure 3.

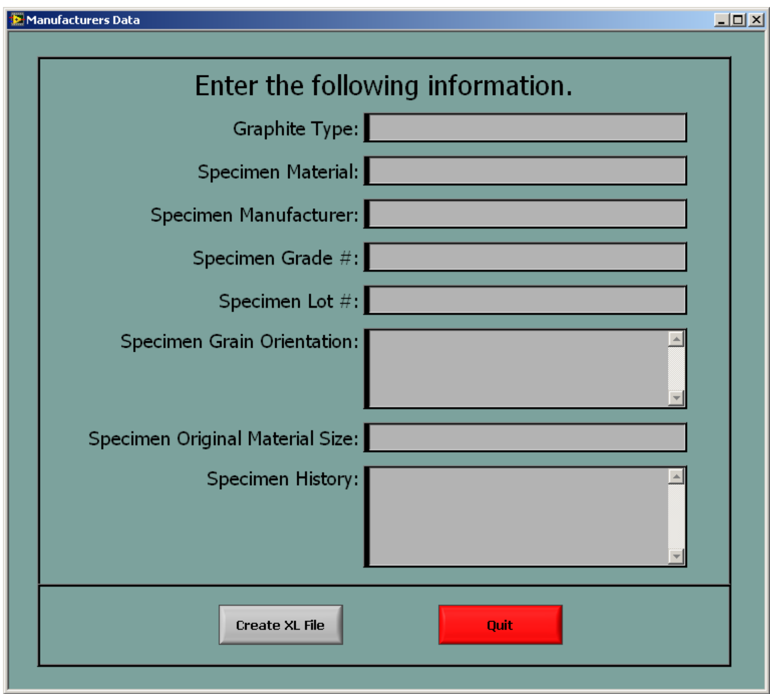
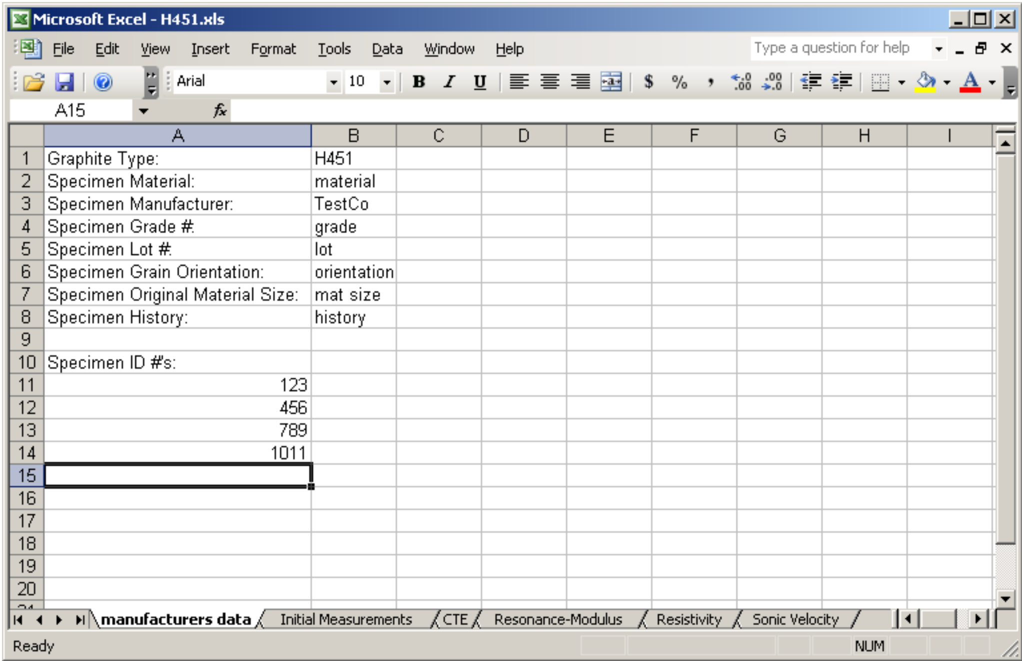


Figure 2. Manufacturer's data user interface screen.



Graphite Type:	H451
Specimen Material:	material
Specimen Manufacturer:	TestCo
Specimen Grade #:	grade
Specimen Lot #:	lot
Specimen Grain Orientation:	orientation
Specimen Original Material Size:	mat size
Specimen History:	history
Specimen ID #'s:	
123	
456	
789	
1011	

Figure 3. Excel data spreadsheet example of the "manufacturer's data" tab.

2.2 Mass and Dimensional Measurements

Dimensional change is one of the key issues affecting the performance of graphite in a neutron environment. Determining volumetric and linear dimensions as functions of temperature and radiological dose will be necessary to understand critical performance measures such as dimensional change turnaround, irradiation creep, and internal stresses imposed upon graphite components. Dimensional and mass measurements are performed to ASTM Standard C559-05, which describes in detail the procedure for making dimensional measurements and calculating bulk density. Dimensional measurements of the specimen radius and length are made with INL calibrated micrometers and calipers. The mass is measured using an INL calibrated electronic balance. Figure 4 shows the dimensional measurement station.

Figure 4. Dimensional measurement station.

The physical and dimensional measurements program user interface is shown in Figure 5. Measurement values are transferred directly from the measurement tools into the LabVIEW software. Once the physical and dimensional measurements of the specimens are taken, the data is automatically written to the Excel spreadsheet under the "Initial Measurements" tab. This data is used to calculate bulk density and is available for other measurement calculations.

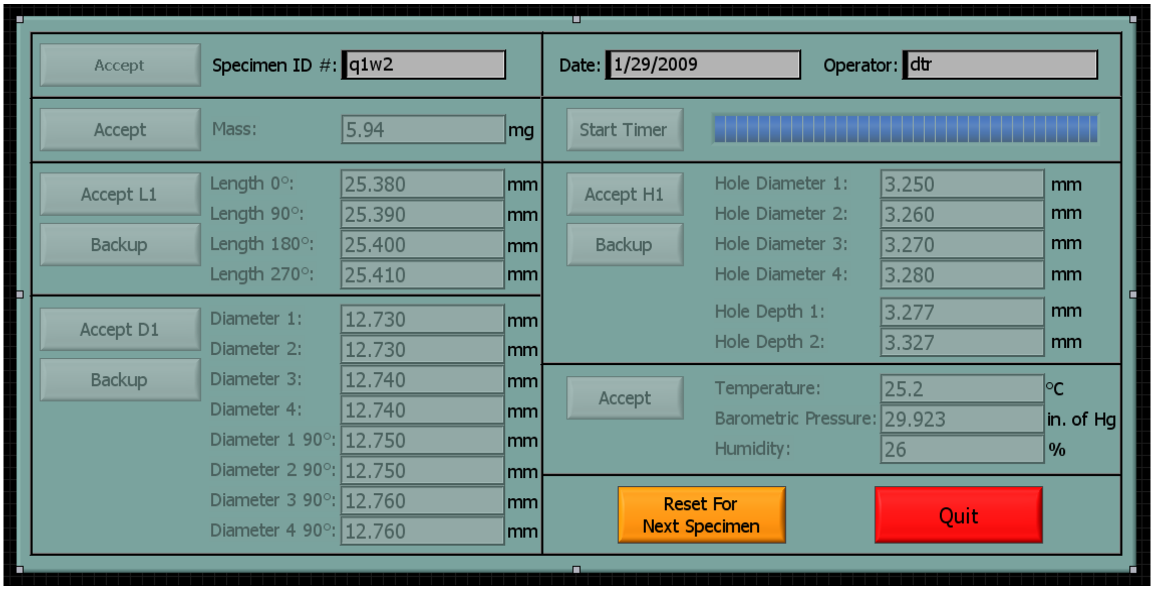


Figure 5. Physical and dimensional measurements program user interface.

2.3 Electrical Resistivity

Electrical resistivity is used as a rapid, simple means to determine grain orientation, structure, and crystallinity of the graphite. In conjunction with optical microscopy, it can be used to determine the microstructural texture of the graphite components without much sample preparation work. Resistivity is measured following ASTM C 611-05. The measurement technique is commonly referred to as 4-point probe. It consists of passing a known current through the sample and measuring the voltage across the sample at known locations. Based on Ohms law, the resistance is determined and the resistivity is calculated from

$$\rho = R \cdot A / L$$

where R is the measured resistance, A is the cross sectional area, and L is the length over which the voltage is measured.

Figure 6 shows the test fixture fabricated at the INL that allows the specimen to be rotated for four measurements of voltage around its periphery. The user interface for electrical resistivity is shown in Figure 7.

The data acquisition screen steps the user through the acquisition process of the voltage and resistance measurement. The program communicates with both a Keithley Model 2182 Nanovoltmeter and a Keithley Model 6220 DC Precision Current Source. Using the current source, a known current is applied across the specimen and the measure voltage is acquired by the software. During data collection, the application calculates the average voltage, average resistance, percent change of the resistance, and ultimately the resistivity. When all of the data has been taken and the user has pressed the "Write Data to File" button, the program saves the results of the test in the resistivity tab of the proper spreadsheet.

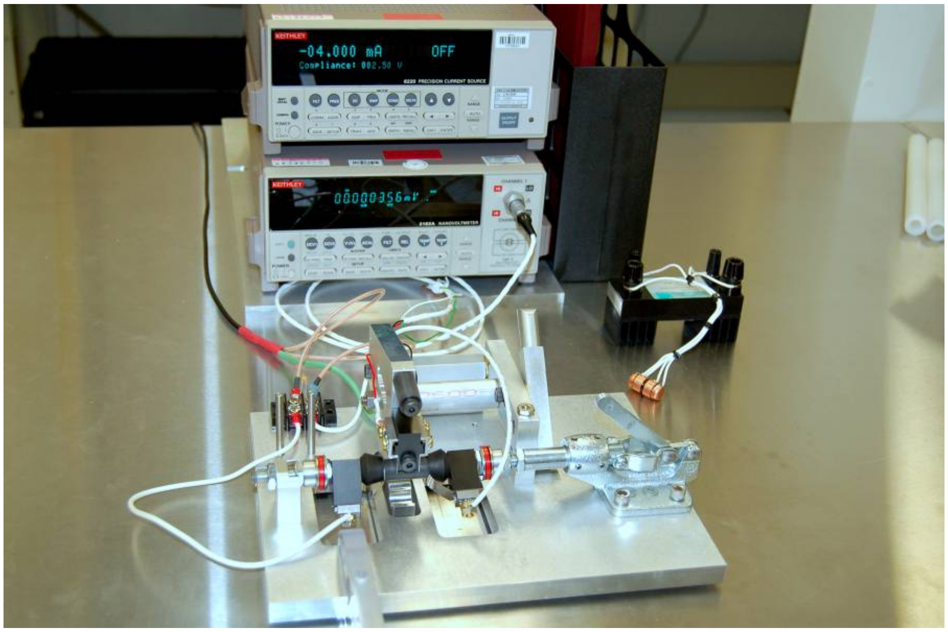


Figure 6. Electrical resistivity measurement station.

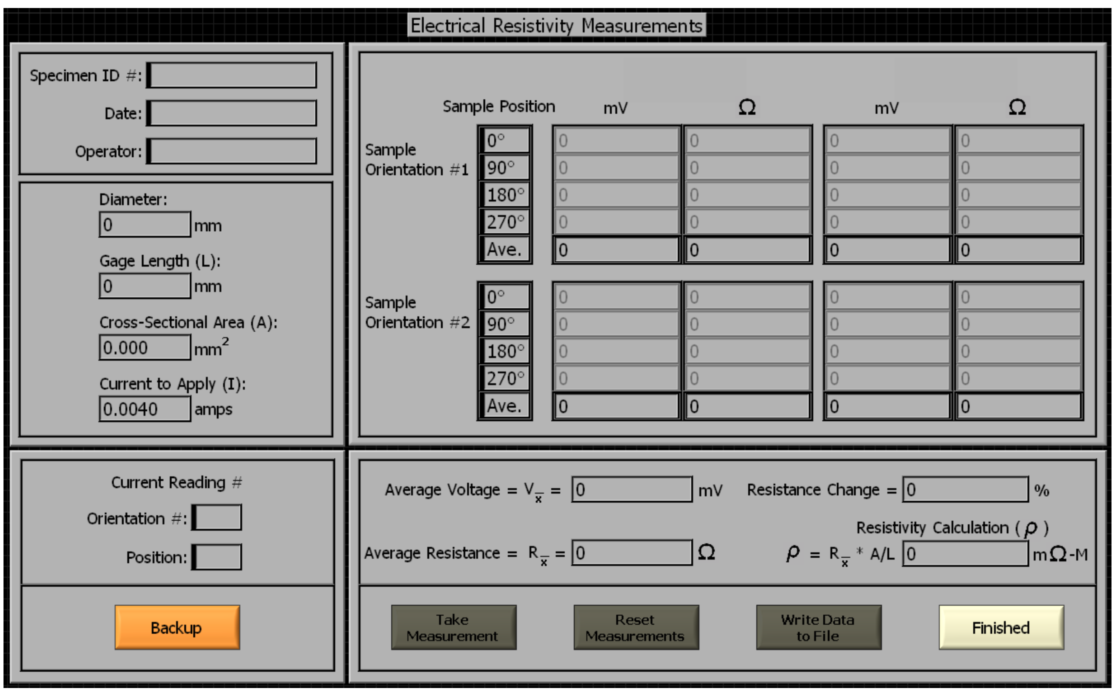


Figure 7. Software user interface for electrical resistivity.

2.4 Approximation of Elastic Modulus from the Measurement of Sonic Velocity

The mechanical properties of graphite are necessary to determine the structural integrity of graphite components. These properties are vital to determining the viability of the structural strength and integrity of the reactor core. The as-received and irradiated values are needed for whole core models, which will be used for the graphite design code. In this measurement the transmitting piezoelectric transducer sends a 2.25 MHz sound wave through the sample. At the opposite end of the sample the acoustic wave is received by another piezoelectric transducer. The sonic velocity of the specimen is the ratio of specimen length to the signal time lapse between transducers. An approximate value for Young's Modulus, E can be obtained from,

$$E = \rho V^2$$

where ρ is the specimen density and V is the sonic velocity.

Figure 8 shows the sonic velocity measurement station. In the foreground are the fixtures for clamping the specimen between the transducer and receiver that were specifically designed and fabricated at the INL for this application. They have unique features that improve measurement accuracy, precision, and efficiency. Specimens are easily and rapidly loaded into the fixture using the cam operated clamp. Measurement precision is improved because the spring loaded clamp applies consistent pressure between the transducers and specimen resulting in repeatable couplant thickness.

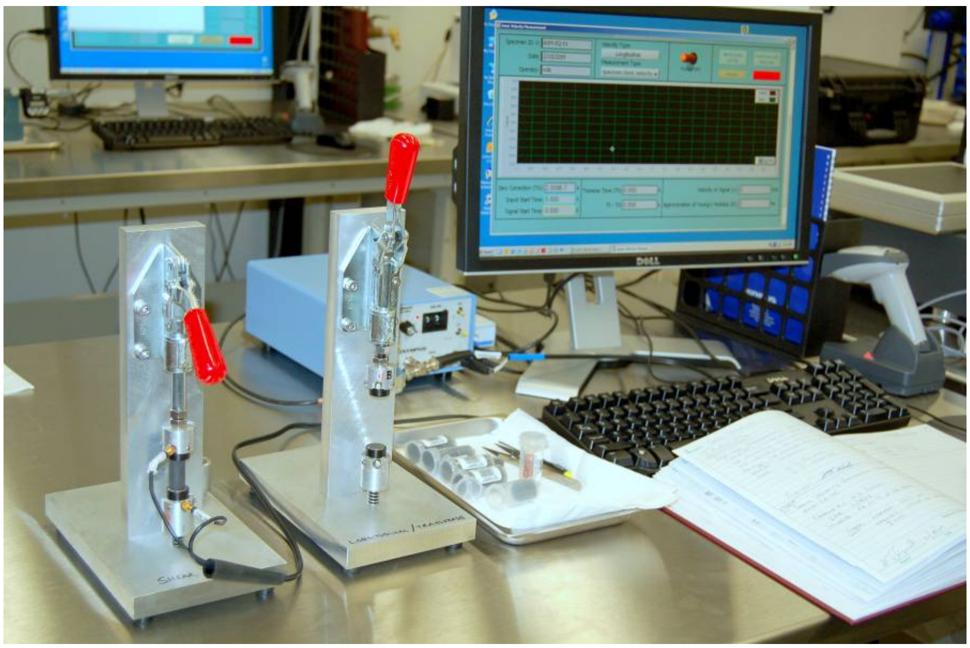


Figure 8. Sonic velocity measurement station.

Figure 9 shows the LabVIEW software user interface that is displayed after scanning the bar code of the specimen to be tested. This screen is used to acquire sonic velocity measurements of a specimen in both the longitudinal and shear directions. Operating much like an oscilloscope, the cursors automatically mark the time between the transmitted wave and the received wave. The specimen length divided by this transit time is the sonic velocity.

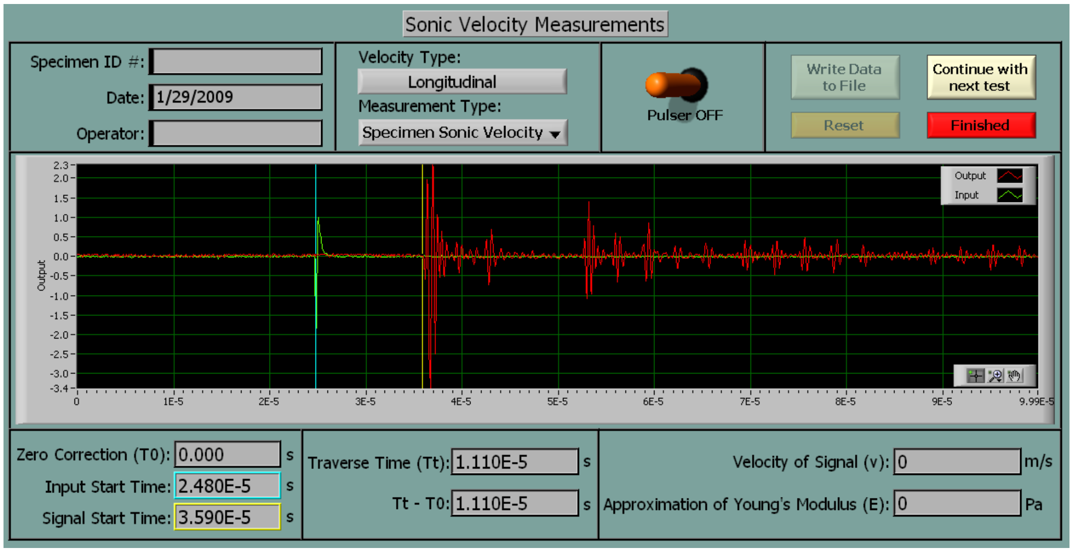


Figure 9. Sonic velocity measurement user interface.

2.5 Modulus of Elasticity by Fundamental Frequency Measurement

As stated above, the mechanical properties of graphite are necessary to determine the structural integrity of graphitic components. These properties are vital to determining the viability of the structural strength and integrity of the reactor core. This test method measures the fundamental resonant frequency of test specimens of suitable geometry by exciting them mechanically with a singular elastic strike. Specimen supports, impulse locations, and signal pick-up points are selected to induce and measure specific modes of the transient vibration of the specimen. The transient signals are analyzed, and the fundamental resonant frequency is isolated and measured by the signal analyzer. The measured fundamental resonant frequency, specimen dimensions and mass are used to calculate the dynamic Young's modulus, shear modulus, and Poisson's ratio per ASTM C747-05 in combination with ASTM C1259-08. The fundamental frequency measurement station is shown in Figure 10.

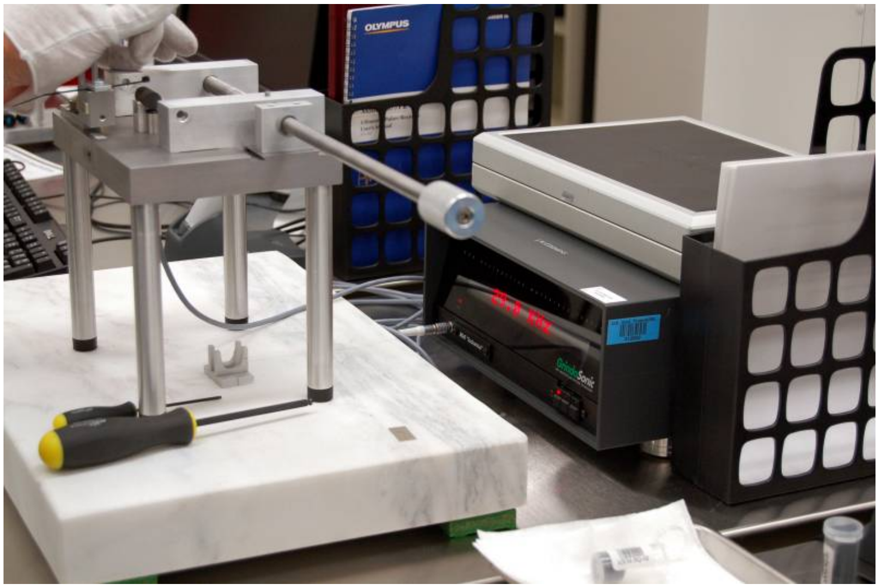


Figure 10. Fundamental frequency measurement station.

Using the LabVIEW software specifically developed for this project, the user scans the bar code of the specimen. After the specimen's bar code has been scanned and the program confirms that fundamental frequency data doesn't already exist for that specimen, the user interface shown in Figure 11 is displayed.

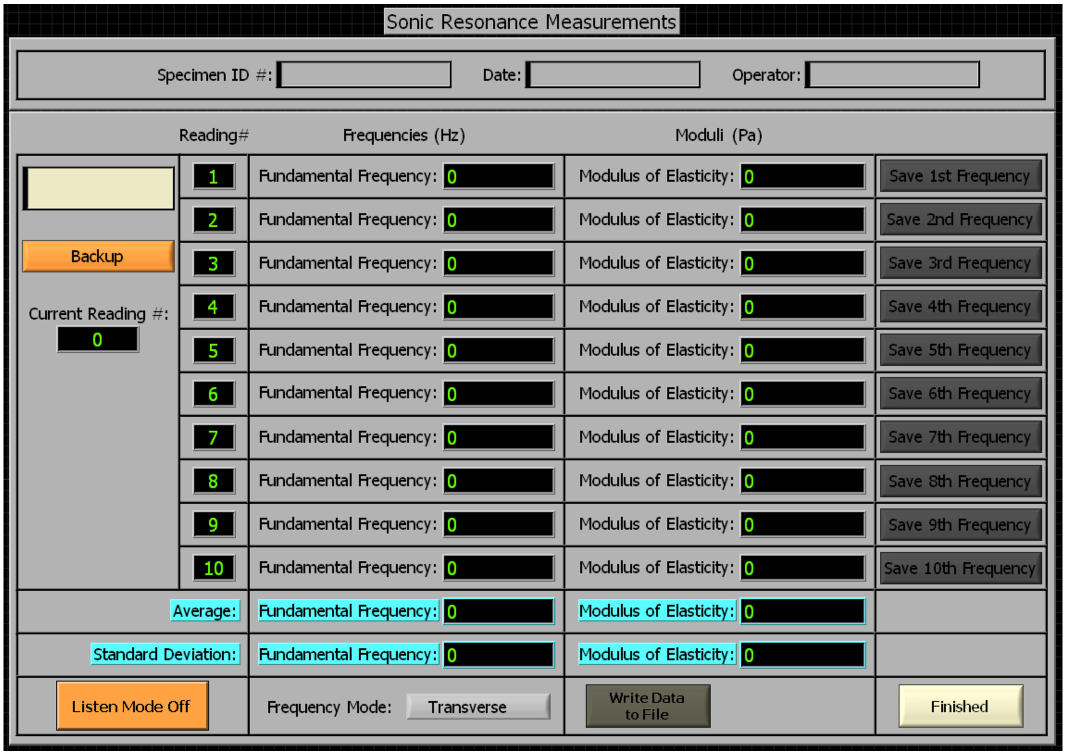


Figure 11. User interface for fundamental frequency measurements.

After placing a specimen in the test fixture, the user excites it by lightly tapping it with a small mechanical impulse. Once the specimen has been excited into vibration, the fundamental frequency is captured by the software and displayed. The modulus of elasticity is calculated and displayed next to the newly acquired frequency. If the results are satisfactory, the user can press the "Save 1st Frequency" button and go on to the next measurement. After all 10 measurements have been made, the results of the test are written to the appropriate Excel spreadsheet.

2.6 Thermal Expansion

Understanding the coefficient of thermal expansion (CTE) for graphite components is critical for determining the dimensional changes that occur as a result of temperature cycles. Localized external stresses can be imposed upon mechanically interlocked graphite core components as the individual pieces experience differential thermal expansion. Internal stresses can occur within larger graphite components if there is a temperature gradient causing differential expansion within the piece (one side has a higher temperature than the other). Finally, the thermal expansion is highly dependent upon the graphite microstructure, such as orientation/anisotropy, pore size and distribution, and crystallinity. Irradiation damage can significantly alter graphite microstructure and thus CTE values. Determining the extent of the changes as a function of irradiation dose and temperature will be a key parameter for reliable calculation of stress states within graphite components, volumetric changes, and irradiation creep rates.

This test method uses a push-rod type dilatometer to determine the change in length of a graphite specimen relative to that of the holder as a function of temperature. The temperature is varied over the desired range at a slow constant heating or cooling rate. The linear thermal expansion and mean coefficient of thermal expansion, α, are calculated from the recorded data using

$$\alpha = \frac{1}{L_0}\frac{\Delta L}{\Delta T}$$

where L_0 is the specimen initial length, ΔL is the change in length, and ΔT is the temperature difference between a specified reference temperature and the temperature at which the change in length was measured. A commercially available push rod dilatometer is used (see Figure 12). It is complete with vendor developed software for instrument control and data acquisition.

Figure 12. Commercial push rod dilatometer for measurement of CTE.

2.7 Thermal Diffusivity

The ability to conduct heat through the graphite core is critical to the passive removal of decay heat. Reduction of the thermal conductivity within graphite can have a significant effect on the passive heat removal rate and thus the peak temperature that the core and, subsequently, the fuel particles will experience during off-normal events. Determining changes to the conductivity as a function of irradiation dose and temperature is important for the HTGR safety analysis. Here, thermal diffusivity (δ) is measured and defined as the ratio of thermal conductivity to volumetric heat capacity by

$$\delta = \frac{k}{\rho C_P}$$

where k is the thermal conductivity, ρ is the density, and C_P is the specific heat.

The measurement is performed on small thin disk shaped specimens. A pulsed laser is used to subject one surface of the specimen to a high-intensity short duration energy pulse. The energy of this pulse is absorbed on the front surface of the specimen and the resulting rear face temperature rise is recorded. The thermal diffusivity is calculated from the specimen thickness and the time required for the rear face temperature to reach 50% of its maximum value. A commercially available Laser Flash Apparatus (LFA), complete with vendor developed software for instrument control and data acquisition, is used as shown in Figure 13.

Figure 13. LFA measurement station for determination of thermal diffusivity.

3. REFERENCES

1. W. Windes, T. Burchell, R. Bratton, "AGC-1 Irradiation Experiment Test Plan," PLN-2497, Rev 0, October 2007.

2. R. L. Bratton and T. D. Burchell, *NGNP Graphite Testing and Qualification Specimen Selection Strategy*, INL/EXT-05-00269, May 2005.

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Appendix A

Assessment Plan and Inspection Report

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Appendix A
Assessment Plan

220.21
04/10/2008
Rev. 00

ASSESSMENT PLAN

Assessment Title: NGNP Work Control Surveillance for Cold Characterization of Graphite

Integrated Assessment System No: IAS081221

Management Assessment ☒ 2/18/08 Independent Assessment: ☐ INSPECTION ☑

PURPOSE AND SCOPE OF ASSESSMENT:
The purpose of this inspection is to evaluate the readiness of the Graphite Characterization Laboratory to conduct work.
The scope will include laboratory C-20 and facilities in which graphite characterization support work is being conducted. The scope needs to include these actions: Assess work control implementation, data collection methods, measuring and test equipment controls, material traceability controls, graphite cleanliness controls, training records for graphite characterization work and equipment operating procedures.
APPLICABLE DOCUMENTS (Identified by applicable title, number, and revision):
LWP -13455 Control of Measuring and Test Equipment
PDD -13450 Calibration and Data Integrity
LWP -13120 Identifying And Controlling Items
LWP - 13014 Determining Quality Levels
MCP -2875 Laboratory Notebooks
MCP -1380 Research and Development Test Control
PLN – 1726 Software Control / 414.A86 with NGNP supplements.
TEAM MEMBERS (Names, functions, and areas evaluating):
Gary Roberts – Lead Assessor
David R. Jensen – QA staff / Lead Assessor in Training.
ORGANIZATION(S)/PROGRAM(S) TO BE EVALUATED (Identify areas, activities and/or organization numbers and titles):
NGNP- Cold Graphite Specimen Characterization
SCHEDULE (Planning, preassessment meeting, field work duration, exit meeting, and final report issuance):
This assessment has been assigned to start on January 5, 2009 and end on March 1, 2009.
CHECKLIST(S)/LINES OF INQUIRY:
Checklist provided.

Manager(s) of Assessed Organization(s)	Manager's Signature for Concurrence	Date
William Windes	[signature]	2-18-09

This form is used with LWP-13750, "Performing Management Assessments," and LWP-13760, "Performing Independent Assessments."
This form can also be used for any other assessment planning activity.

ASSESSMENT PLAN

Gary Roberts	[signature]	2/18/09 *
Lead Assessor/Team Leader	Lead Assessor/Team Leader Signature	Date

Diane Croson	[signature]	2/18/09
Cognizant Director/Management System Leader	Cognizant Director/Management System Leader Signature	Date

* Assessment Plan written prior to 1/28/09 and all parties were notified of inspection focus ~~& timing~~ 2/18/09 timing.
[signature] 2/18/09

ASSESSMENT PLAN

INSTRUCTIONS FOR COMPLETION OF FORM 220.21

PURPOSE AND SCOPE OF ASSESSMENT: Describe the purpose of the assessment. Purpose provides the reason or objectives for "why" the assessment is being performed. Describe the scope of the assessment. Scope provides the boundaries within which the assessment activity is be performed. Scope should include the "what," "where," and "depth" of the assessment.

APPLICABLE DOCUMENTS: Identified by applicable number, title, and revision of the documents that are the basis for which performance will be evaluated.

be used as a guide throughout the assessment to evaluate performance against requirements and expectations. Checklist(s) and lines of inquiry vary in format, content, and level of detail to focus the assessor on the mission and objectives of the program, system, or process being assessed. They include the performance criteria to the established assessment scope and may include lists of interview questions, major elements of programs, or detailed process work. An attached document is acceptable.

MANAGERS OF ASSESSED ORGANIZATION(S): Identify the manager(s) of the organizations to be assessed. If appropriate, enter the higher level of management when multiple organizations are identified within one directorate.

MANAGER'S SIGNATURE FOR CONCURRENCE: Obtain the manager(s) of the assessed organization's concurrence of the assessment plan.

LEAD ASSESSOR/TEAM LEADER: Enter the name of the lead assessor or team leader.

LEAD ASSESSOR/TEAM LEADER SIGNATURE: Lead assessor's/team leader's signature after concurrence by the assessed organization(s) have been obtained.

COGNIZANT DIRECTOR/MANAGEMENT SYSTEM LEADER: Enter the name of the sponsoring director and management system leader.

COGNIZANT DIRECTOR/MANAGEMENT SYSTEM LEADER SIGNATURE: Sponsoring director's and management system leader's signature.

This form is used with LWP-13750, "Performing Management Assessments," and LWP-13760, "Performing Independent Assessments."
This form can also be used for any other assessment planning activity.

INSPECTION REPORT
IAS081221 NGNP Work Control Surveillance for Cold Characterization of Graphite

Inspection Planning

See attached Form 220.21

Inspection Checklist and Result

Item No.	Items to be inspected and expected condition (Include topic, reference to requirement, and method used to evaluate)	Criteria Met Yes/No/ N/A	Results (Include condition observed and documents reviewed)
	M&TE		
1	**Is there an equipment list or log that identifies all calibrated M&TE used by the organization?** NQA-1 Requirement 12 Section 401 LWP-13455, section 4.2.1	**Yes**	**An equipment list for all M&TE is listed in the Laboratory Notebook for each instrument. All instruments are uniquely identified. The list contains as available the name, model, serial number, INL property number, and calibration date.** **Information is documented in the following Laboratory Notebooks:** • **LAB-1317 pg. 4** • **LAB-1318 pg. 4** • **LAB-1319 pg. 4** • **LAB-1320 pg. 4** • **LAB-1321 pg. 4** • **LAB-1322 pg. 4**
2	**Is there a description or name of the device or system identified?** NQA-1 Requirement 12 Section 303.6 LWP-13455, section 4.2.1	**Yes**	**A description of the instrument is described in the Laboratory Notebook located at each instrument station.** **Information is documented in the following Laboratory Notebooks:** • **LAB-1317 pg. 4** • **LAB-1318 pg. 4** • **LAB-1319 pg. 4** • **LAB-1320 pg. 4** • **LAB-1321 pg. 4** • **LAB-1322 pg. 4**

INSPECTION REPORT
IAS081221 NGNP Work Control Surveillance for Cold Characterization of Graphite

3	**Is there a unique M&TE identification number of the device or system identified and is it tagged?** NQA-1 Requirement 12 Section 303.6 LWP-13455, section 4.2.1	**Yes**	**Each M&TE has an identification number listed in the Laboratory Notebook for each instrument and each is tagged with that identification number. Identification numbers visually checked.** **Information is documented in the following Laboratory Notebooks:** • **LAB-1317 pg. 4** • **LAB-1318 pg. 4** • **LAB-1319 pg. 4** • **LAB-1320 pg. 4** • **LAB-1321 pg. 4** • **LAB-1322 pg. 4**
4	**Is there a calibration interval identified and tagged?** NQA-1 Requirement 12 Section 303 LWP-13455, section 4.2.1	**Yes**	**The calibration interval is identified for each instrument as noted in the instruments Laboratory Notebook. The calibration interval is tagged on each piece of M&TE. All instruments were visually checked to have calibration tags.** **Information is documented in the following Laboratory Notebooks:** • **LAB-1317 pg. 4** • **LAB-1318 pg. 4** • **LAB-1319 pg. 4** • **LAB-1320 pg. 4** • **LAB-1321 pg. 4** • **LAB-1322 pg. 4**
5	**Is the specific location for M&TE to be stored identified, if appropriate?** NQA-1 Requirement 12 Section 303.3 LWP-13455, section 4.2.1	**Yes**	**All project M&TE is located in Laboratory C-20 at the IRC.**

INSPECTION REPORT
IAS081221 NGNP Work Control Surveillance for Cold Characterization of Graphite

Item No.	Items to be inspected and expected condition (Include topic, reference to requirement, and method used to evaluate)	Criteria Met Yes/No/ N/A	Results (Include condition observed and documents reviewed)
6	**Is there history file for each item or system containing:** ▪ **The calibration results** ▪ **Issued M&TE out-of-tolerance forms** ▪ **Applicable Nonconformance reports (NCRs)** ▪ **Calibration interval** ▪ **Date of last calibration** ▪ **Certificates of calibration when calibrated by a vendor** ▪ **Calibration expiration date** ▪ **Unique instrument/environmental requirements** ▪ **Repair history documentation** NQA-1 Requirement 12 Section 402 LWP-13455, section 4.2.2	**Yes**	**All current required information is inserted or recorded into the Laboratory Notebook associated to the instrument or available through ICAL.** ▪ **Calibration results are tracked through the ICAL system or as noted in Laboratory Notebooks.** • **M&TE documented in LAB-1317 is tracked trough ICAL.** • **M&TE documented in LAB-1318 is tracked trough ICAL.** • **M&TE documented in LAB-1319 pg 10, and 25 is calibrated by manufacturer.** • **M&TE documented in LAB-1320 pg. 4. Calibration not required per manufacturer.** • **M&TE documented in LAB-1321 pg. 10 is calibrated by manufacturer.** • **M&TE documented in LAB-1322 pg. 5-8 is calibrated by manufacturer.** ▪ **Currently there are no out-of-tolerance forms. Future out-of-tolerance forms are to be inserted in Laboratory Notebooks.** ▪ **Currently there are no NCR's. NCR's are tracked though the ICARE system.** ▪ **Instruments are within initial calibration. Expiration date is tagged on the instrument, logged in the Laboratory Notebook and tracked though the ICAL system. See M&TE #1** ▪ **Certificates of Calibration by vendor are inserted in the Laboratory Notebook or available in ICAL. See above.** ▪ **No unique instrument/environmental requirements.** ▪ **No repairs have been performed; no repair history documented. Future repairs will be noted in Laboratory Notebooks.**

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Item No.	Items to be inspected and expected condition (Include topic, reference to requirement, and method used to evaluate)	Criteria Met Yes/No/ N/A	Results (Include condition observed and documents reviewed)
7	**Has a master list of all calibration instruments, measurement standards, and reference materials used by the organization been maintained and updated?** NQA-1 Requirement 12 Section 401 LWP-13455, section 4.2.3	**Yes**	**A list of all calibration instruments, measurement standards, and reference materials is tracked thorough the ICAL system or in Laboratory Notebooks.** **Information is documented in the following Laboratory Notebooks:** • **LAB-1317 pg. 4,9-11** • **LAB-1318 pg. 4,9-14** • **LAB-1319 pg. 4-10,16** • **LAB-1320 pg. 4,6-7** • **LAB-1321 pg. 4,5-7** • **LAB-1322 pg. 4,7**
8	**Are Calibration Certificates (A document that presents calibration results and other information relevant to a calibration) if required for external customers documents maintained?** NQA-1 Requirement 12 Section 402 LWP-13455, section 4.2.4	**Yes**	**See M&TE #6**
9	**Are Out-of-Tolerance reports of standards (issued by the calibrating organization) documents maintained?** NQA-1 Requirement 12 Section 402 LWP-13455, section 4.2.4	**N/A**	**All current calibrations are within tolerance and there are no Out-of-Tolerance reports.**

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10	**Are Data sheet documents maintained?** NQA-1 Requirement 12 Section 401 LWP-13455, section 4.2.4	Yes	**Data sheets are maintained by the ICAL system for instruments calibrated by the INL Calibration Laboratory. For calibration before use instruments, the data is kept in the instruments Laboratory Notebook.**
	HANDLING AND STORING M&TE		
1	**Are M&TE stored, used, transported, and handled in an environment that accuracy, stability or performance is not affected adversely?** NQA-1 Requirement 12 Section 303.3 LWP-13455, section 4.3.1	Yes	**M&TE is stored and used and handled in a controlled environment in Laboratory C-20 at the IRC so that accuracy, stability or performance is not affected adversely.** **M&TE, when transported, will be transported in protective containers with appropriate padding so that accuracy, stability or performance is not affected adversely.**
2	**Are work areas and calibrated equipment clean and good housekeeping practices being followed?** NQA-1 Requirement 12 Section 303.3 LWP-13455, section 4.3.3 and 4.3.3.1	Yes	**Visual inspection during a walk through show work areas and calibrated equipment in Laboratory C-20 are clean and good housekeeping practices are being followed.**
3	**Are suitable shock absorbing and packing materials being used to protect instrumentation from adverse conditions such as temperature, humidity, vibration and dust during shipping?** NQA-1 Requirement 12 Section 303.3 LWP-13455, section 4.3.4 and 4.3.5	Yes	**In laboratory C-20 protective containers with appropriate padding are available to surround instruments during shipping to protect instrumentation against adverse conditions such as temperature, humidity, vibration, and dust.**
	ESTABLISHING AND CHANGING M&TE CALIBRATION INTERVALS		
1	**Are all new M&TE calibrated before use and calibration stickers present?** NQA-1 Requirement 12 Section 303.6 LWP-13455, section 4.4.1	Yes	**All M&TE are currently calibrated and current calibration stickers are affixed to the M&TE.** **Visually verified stickers attached to instrument.**

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2	**Have periodic calibration intervals for M&TE been established and being followed.** NQA-1 Requirement 12 Section 303.5 LWP-13455, section 4.4.2	**Yes**	**Instruments calibration intervals are tracked and assigned by ICAL system.** **Instruments that are to be calibrated by user follow the manufacturer recommendation for calibration intervals as out lined in manuals or written instructions from the manufacturer.** **See M&TE # 1.**
	ESTABLISHING PROCEDURES AND METHODS FOR CALIBRATING M&TE		
1	**Are procedures in place for operation of equipment?** NQA-1 Requirement 12 Section 303 LWP-13455, section 4.5.1	**Yes**	**Detailed operating instructions which include operator's instructions, manufacturer's instructions, and ASTM instructions are located in the Laboratory Notebook for each instrument or in the laboratory.** **Specific ASTM's, operator's instructions, and manufacturers instructions are listed in the associated Laboratory Notebook and or available in the laboratory.** **Information is documented in the following Laboratory Notebooks:** • **LAB-1317 pg. 4-6** • **LAB-1318 pg. 4-6** • **LAB-1319 pg. 18** • **LAB-1320 pg. 4-5** • **LAB-1321 pg. 4** • **LAB-1322 pg. 4**
2	**Are procedures in place handling and preparation of items?** NQA-1 Requirement 12 Section 303 LWP-13455, section 4.5.1	**Yes**	**Personnel follow ASTM C 559 as the guiding procedure for handling and preparation of specimens.**

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Item No.	Items to be inspected and expected condition (Include topic, reference to requirement, and method used to evaluate)	Criteria Met Yes/No/ N/A	Results (Include condition observed and documents reviewed)
3	**Are procedures in place for calibration of instrument by an operator or technician?** NQA-1 Requirement 12 Section 303 LWP-13455, section 4.5.1	Yes	**Procedures for calibration of an instrument by an operator or technician are provided in manuals and instruction from the manufacturer. Manuals are located in the Laboratory or in Laboratory Notebooks.** **Information is documented in the following Laboratory Notebooks:** • **LAB-1321 pg. 10** • **LAB-1322 pg. 5-6**
	CALIBRATING BEFORE USE BY USER		
1	**Is the Date of the calibration documented?** NQA-1 Requirement 12 Section 303.6 LWP-13455, section 4.7.2	N/A	**Instruments are currently within initial calibration. No calibration by user date available. Future calibrations, the calibration date will be recorded in the Laboratory Notebook after each new calibration is made.**
2	**Is the standard used identified and documented?** NQA-1 Requirement 12 Section 302 LWP-13455, section 4.7.2	N/A	**Instruments are currently within initial calibration. Standards used to calibrate will be identified and documented in the Laboratory Notebook.**
3	**Is the procedure used identified and documented?** NQA-1 Requirement 12 Section 303 LWP-13455, section 4.7.2	Yes	**See ESTABLISHING PROCEDURES AND METHODS FOR CALIBRATING M&TE # 3**
4	**Is the person who performed the calibration identified and documented?** NQA-1 Requirement 12 Section 303 LWP-13455, section 4.7.2	N/A	**Instruments are currently within initial calibration. The name of the operator or technician who calibrates the instrument will be recorded in the respective Laboratory Notebook.**
5	**Are records maintained to show the calibrator is trained?** NQA-1 Requirement 12 Section 303 LWP-13455, section 4.7.3	Yes	**All training records of operators or technicians for the calibration of equipment are recorded in the Laboratory Notebook associated to the instrument.** **Information documented in the following Laboratory Notebooks:** • **LAB-1321 pg. 16-17** • **LAB-1322 pg. 9-10**

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TEST UNCERTAINTY RATIOS (TUR) AND ENGINEERING ANALYSIS			
1	**Have Test Uncertainty Rations (TUR) been established?** NQA-1 Requirement 12 Section 302 LWP-13455, section 4.8.1	Yes	Test Uncertainty Ratios are established by the INL Calibration Laboratory.
2	**If the TUR is less than 4:1, has an uncertainty analysis been performed?** NQA-1 Requirement 12 Section 302 LWP-13455, section 4.8.2	N/A	No Test Uncertainty Ratios less than 4:1.
CONTROLLING OUT-OF-CALIBRATION OR OUT-OF-TOLERANCE M&TE			
1	**Has out-of-calibration equipment been tagged and removed from service?** NQA-1 Requirement 12 Section 303 LWP-13455, section 4.10.1	N/A	There are no out-of-calibration instruments. All instruments are in service.
2	**Has a PIR per LWP-13840 or an NCR per LWP-13830 been initiated and processed to address the deficiency?** NQA-1 Requirement 12 Section 303 LWP-13455, section 4.10.2.1	N/A	There are no current PIR's or NCR's at this time.
3	**Has out-of-calibration equipment been segregated from work area?** NQA-1 Requirement 12 Section 303 LWP-13455, section 4.10.2.2	N/A	All equipment is calibrated. No segregation is required.
4	**If out-of-calibration conditions exist has the affected data been reviewed and accepted for use?** NQA-1 Requirement 12 Section 303 LWP-13455, section 4.10.5	N/A	No out-of-calibration conditions exist.

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TRACEABILITY OF CALIBRATIONS AND MEASUREMENTS			
1	**Are calibrations standards traceable to national or international standards?** NQA-1 Requirement 12 Section 301 LWP-13455, section 4.14.4	**Yes**	**All calibrations provided by the INL Calibration Laboratory have standards traceable to National Standards.** **Calibration by user, standards are traceable to national standards or international standards. Calibration by user, standards are located in:** • **LAB-1321 pg. 5-7** • **LAB-1322 pg. 7**
2	**Has a usage log or documentation system been established and maintained for M&TE or for standards used for calibration or acceptance?** NQA-1 Requirement 12 Section 401 LWP-13455, section 4.14.5	**Yes**	**M&TE and standards performed by the INL Calibration Laboratory are tracked through the ICAL system.** **Calibration by user is traceable to national or international standards. Calibration by user, standards are located in:** • **LAB-1321 pg. 5-7** • **LAB-1322 pg. 7**
3	**Has the M&TE unique identification number been documented in the usage log or documentation system?** NQA-1 Requirement 12 Section 303 LWP-13455, section 4.14.5	**Yes**	**All M&TE unique identification numbers used are tracked through the ICAL system, Laboratory Notebooks and laboratory C-20 Data Acquisition software.** **Information is documented in the following Laboratory Notebooks:** • **LAB-1317 pg. 4** • **LAB-1318 pg. 4** • **LAB-1319 pg. 4** • **LAB-1320 pg. 4** • **LAB-1321 pg. 4** • **LAB-1322 pg. 4**

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4	**Has the Date(s) M&TE was used been documented in the usage log or documentation system?** NQA-1 Requirement 12 Section 303 LWP-13455, section 4.14.5	**Yes**	**Laboratory Notebooks and Laboratory C-20 Data Acquisition Systems document the date M&TE are used.**
5	**Has the work package number or other identification information, as applicable been documented in the usage log or documentation system?** NQA-1 Requirement 12 Section 303 LWP-13455, section 4.14.5	**Yes**	**This is accomplished by the laboratory C-20 Data Acquisition system. The Data Acquisition system captures the date the M&TE is used and the measurement information for each specimen.**
	MAINTAINING CALIBRATION FACILITIES, EQUIPMENT, AND REFERENCE MATERIALS		
1	**Are in-service checks of M&TE and reference standards between calibrations performed when relevant?** NQA-1 Requirement 12 Section 302 LWP-13455, section 4.15.7	**Yes**	**Continuous verification is performed as outlined by instructions in Laboratory Notebooks for each instrument.** **Information is documented in the following Laboratory Notebooks:** • **LAB-1317 pg. 4, 7-8, 17** • **LAB-1318 pg. 4, 7-8, 22** • **LAB-1319 pg. 18, 11-17, 24** • **LAB-1320 pg. 5-6** • **LAB-1321 pg. 4,10** • **LAB-1322 pg. 4-6**
	CALIBRATION AND DATA INTEGRITY		
1	**Are calibrations performed by qualified technicians using approved procedures? The procedures shall include the type of calibration standards to be used.** NQA-1 Requirement 12 Section 401 PDD-13450, section 3.3	**Yes**	**Calibrations that are performed by the INL Calibration Laboratory and follow their procedures.** **Calibration before use is performed by qualified operators or technicians. See CALIBRATING BEFORE USE BY USER #5.** **Instructions are described in the Laboratory Notebook and manufacturer instructions.**

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2	**Are calibration standards traceable to NIST or internationally recognized standards organizations for calibration of M&TE?** NQA-1 Requirement 12 Section 401 PDD-13450, section 5.11	Yes	**There three types of calibrations associated to this laboratory.** ▪ **The INL Calibration Laboratory performs the calibration.** ▪ **The operator performs the calibration.** ▪ **Calibration is not required.** **The Calibration Laboratory has standards traceable to NIST.** **Calibration by User, standards are traceable to national or international standards. Calibration by user, standards are located in:** • **LAB-1321 pg. 5-7** • **LAB-1322 pg. 7**
3	**Where traceability to international, national, or intrinsic standards of measurement is not available, are traceability requirements satisfied by one of the following:** ▪ **Participation in a suitable program of inter-laboratory comparisons or proficiency testing** ▪ **Internationally accepted standards in the field concerned** ▪ **Suitable reference materials** ▪ **Ratio or reciprocity-type measurements** ▪ **Mutual consent standards which are clearly specified and mutually agreed upon by all parties concerned** NQA-1 Requirement 12 Section 302 PDD-13450, section 5.11	Yes	**All calibrations are traceable to international or national standards.**

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4	**Are calibration stickers attached to each M&TE? Are the calibration dates and expiration dates identified on the sticker?** NQA-1 Requirement 12 Section 301 PDD-13450, section 5.13	**Yes**	**All M&TE have calibration stickers that specify the date and expiration of date of the instrument.** **Physical verification of M&TE recorded in Laboratory Notebooks. Information is documented in the following Laboratory Notebooks:** • **LAB-1317 pg. 4** • **LAB-1318 pg. 4** • **LAB-1319 pg. 4** • **LAB-1320 pg. 4** • **LAB-1321 pg. 4** • **LAB-1322 pg. 4**
	IDENTIFYING AND CONTROLLING ITEMS		
1	**Has material been identified with batch number, heat number, lot number, reel number, serial number and is present and legible?** NQA-1 Requirement 08 Section 201 LWP-13120, Appendix A section 2	**Yes**	**The samples are identified by grade such as PCEA. From cut up diagrams a unique identification number is assigned the sample. This identification number is then laser etched on to the sample for traceability.** **Specimens accepted by INL inspector for AGC-1. QA number 149181.**
2	**Is there a signed chain-of-custody?** NQA-1 Requirement 08 Section 201 LWP-13120, Appendix A section 1	**N/A**	**Chain-of-custody is not required. Items are tracked by traceable identification numbers.**
3	**Is there a certificate-of-conformance?** NQA-1 Requirement 08 Section 201 LWP-13120, Appendix A section 2	**Yes**	**Certificate-of-Conformance for each grade of graphite is provided in the AGC-1 data package.**
4	**Has a Q/A number been applied to the material and documented onto work control documents?** NQA-1 Requirement 08 Section 201 LWP-13120, Appendix A section 1	**Yes**	**Material has been Green Tagged. QA number 149181. As new graphite characterization takes place unique specimen numbers will be traceable to a QA number associated with the graphite source material.**

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5	**Has material been marked by one or more of the acceptable means as specified by engineering:** ▪ **low-stress stamping** ▪ **vibro-etching** ▪ **adhesive labels** ▪ **tags** ▪ **inks/markers/paints** ▪ **laser etching?** NQA-1 Requirement 08 Section 202 LWP-13120, Appendix B	Yes	**Specimens are marked by laser etching identification numbers into the specimen.** **Specimens accepted by INL inspector for AGC-1, QA number 149181.**
6	**Are markings or identifications clear, legible, indelible, secure and readily identifiable to the item(s)?** NQA-1 Requirement 08 Section 202 LWP-13120, Appendix B	Yes	**Specimens are clearly marked and accepted by project personnel. Specimens accepted by INL inspector for AGC-1, QA number 149181.**
7	**Are markings or identifications affixed or applied using materials and methods which do not detrimentally affect the operation, function or service life of the item?** NQA-1 Requirement 08 Section 202 LWP-13120, Appendix B	Yes	**Specimens are laser etched with identification numbers.** **Specimens accepted by INL inspector for AGC-1, QA number 149181.**
8	**Are items stored in an approved storage area?** NQA-1 Requirement 08 Section 303 LWP-13120, Appendix D	Yes	**Laboratory C-20 at the IRC is an approved storage area for graphite use in support of VHTR TDO.**
9	**Are any special storage requirements required such as temperature, humidity, or other environmental conditions?** NQA-1 Requirement 08 Section 303 LWP-13120, Appendix D	Yes	**No special storage requirements such as temperature, humidity, or other environmental conditions are required.**

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10	**Are materials properly segregated (placed in separate rooms, shelves, containers, or are clearly marked with the QL designation) based on quality level?** NQA-1 Requirement 08 Section 202 LWP-13120, Appendix D	**Yes**	**The graphite samples are green tagged and segregated in a locked container in the laboratory C-20. Other material in the laboratory C-20 is in process of commercial grade dedication. This material is segregated away by being stored in separate containers.**
11	**For material that cannot be segregated due to its size and handling restrictions are the following conditions meet:** ▪ **the area will be roped off** ▪ **the area will be posted to indicate that the area is a Quality Material Control Area, if applicable** ▪ **restrictions will be imposed for entry and removal of material** ▪ **identification markings will be protected from deterioration resulting from environmental exposure** ▪ **material will be periodically inspected to ensure item identification is preserved?** NQA-1 Requirement 08 Section 202 LWP-13120, Appendix D	**N/A**	**Segregation due to size and handling is not an issue.**
12	**Are storage areas posted to designate storage level?** NQA-1 Requirement 13 Section 100 LWP-13120, Appendix D	**Yes**	**Storage area is posted to storage level "D".**
13	**Are storage areas posted to designate presence of Quality Accepted materials?** NQA-1 Requirement 08 Section 100 LWP-13120, Appendix D	**Yes**	**The storage area is posted with a sign and displays Green Tag number 149181 as Quality Accepted material.**
14	**Is access to storage areas controlled?** NQA-1 Requirement 08 Section 100 LWP-13120, Appendix D	**Yes**	**Laboratory C-20 at the IRC is an access controlled laboratory.**

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15	**For out door storage have the following requirements been met** ▪ **Weatherproof coverings are flame resistant** ▪ **Weatherproof coverings provide drainage and ensure air circulation** ▪ **Properly secured to prevent moisture and wind damage** NQA-1 Requirement 08 Section 303 LWP-13120, Appendix D	**Yes**	**No outdoor storage, requirement does not apply.**
16	**Has quality accepted material been segregated and identified by appropriate quality status indicators?** NQA-1 Requirement 08 Section 202 LWP-13120, Appendix D	**Yes**	**Quality material is segregated, stored in a locked container, and tagged with a Green Tag Number 149181.**
DETERMINING QUALITY LEVELS			
1	**Has a quality level determination been performed by Quality Level Analysts for work being done?** NQA-1 Part IV, Subpart 4.2, 300 LWP-13014, Section 4.6	**Yes**	**The Quality Level determination has been done by a Quality Level Analyst and documented in REC-000015.**
2	**Has the quality level determination (QLD) been performed by personnel qualified to perform the determinations?** NQA-1 Part IV, Subpart 4.2, 300 LWP-13014, Section 4.6	**Yes**	**The Analyst is selected from a list of Qualified Analysts. No one is added to the Qualified Analysts list unless they have completed the required training.**
3	**Has the quality level determination (QLD) been reviewed and approved by personnel qualified to approve the determinations?** NQA-1 Part IV, Subpart 4.2, 300 LWP-13014, Section 4.6	**Yes**	**The QLD is approved by the responsible Manager and documented in REC-000015.**
MAINTAINING LABORATORY NOTEBOOKS			

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1	**Are laboratory notebooks INL issued notebooks with the Best Management Practice label and affix inside the front cover?** NQA-1 Requirement 5 and 6 MCP-2875, Section 4.1.3	**Yes**	**All Laboratory Notebooks have a Best Management Practice label and they are affixed inside the front cover of the Laboratory Notebooks.** **Information is documented in the following Laboratory Notebooks:** • **LAB-1317 pg. Inside cover** • **LAB-1318 pg. Inside cover** • **LAB-1319 pg. Inside cover** • **LAB-1320 pg. Inside cover** • **LAB-1321 pg. Inside cover** • **LAB-1322 pg. Inside cover**
2	**Are laboratory notebooks registered through the Electronic Document Management System?** NQA-1 Requirement 5 and 6 MCP-2875, Section 4.1.4	**Yes**	**Each Laboratory Notebook is registered through the Electronic Document Management System.** **Information is documented in the following Laboratory Notebooks:** • **LAB-1317 pg. Inside cover** • **LAB-1318 pg. Inside cover** • **LAB-1319 pg. Inside cover** • **LAB-1320 pg. Inside cover** • **LAB-1321 pg. Inside cover** • **LAB-1322 pg. Inside cover**
3	**Have notebooks marked "Research and Technical Notebook" incorrectly used as either a logbook or a journal been clearly marked "Logbook" or "Journal" and the EDMS Document Number cancelled?** NQA-1 Requirement 5 and 6 MCP-2875, Section 4.2.3	**N/A**	**No Research or Technical Notebooks are being used as a Laboratory Notebook or a journal. EDMS Document Number cancellation not needed.**

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4	**Have notebooks containing Sensitive Unclassified Information been marked so on the front of the notebook?** NQA-1 Requirement 5 and 6 MCP-2875, Section 4.2.8	**N/A**	**No Laboratory Notebooks contain Sensitive Unclassified Information.**
5	**Are notebooks being properly controlled?** NQA-1 Requirement 5 and 6 MCP-2875, Section 4.2.6	**Yes**	**All Laboratory Notebooks are kept in Laboratory C-20 of the IRC which is a controlled building and C-20 is a locked room.** **Laboratory Notebooks inspected: LAB-1317, LAB-1318, LAB-1319, LAB-1320, LAB-1321, and LAB-1322.**
6	**Have staff members been trained in the proper use of laboratory notebooks?** NQA-1 Requirement 5 and 6 MCP-2875, Section 4.3.1	**Yes**	**All operators or technicians have been trained in the proper use of Laboratory Notebooks.** **Reviewed operators or technicians INL Laboratory Notebook training history in the INL TRAINS system.**
7	**Are laboratory notebooks included in the record reviews?** NQA-1 Requirement 5 and 6 MCP-2875, Section 4.3.2	**Yes**	**Laboratory Notebooks are initially identified as a record when assigned a number through EDMS. A period review of Laboratory Notebook content is performed by Managers, QA, and the PI. Final record review is completed in accordance to LWP-1202 and PLN 1485.**
8	**Have notebooks been designated as Working, Active or Inactive?** NQA-1 Requirement 5 and 6 MCP-2875, Section 4.4.3	**Yes**	**All Laboratory Notebooks are considered Working Notebooks. There are no inactive Laboratory Notebooks in for this project.** **Laboratory Notebooks inspected: LAB-1317, LAB-1318, LAB-1319, LAB-1320, LAB-1321, and LAB-1322.**
9	**Are Logbooks properly stored based on the current laboratory notebook designation (Working or Active-protected from loss, Inactive- turned over to records coordinator)?** NQA-1 Requirement 5 and 6 MCP-2875, Section 4.4.4	**Yes**	**All Laboratory Notebooks are Working Notebooks and are stored in Laboratory C-20 at the IRC.** **Laboratory Notebooks inspected: LAB-1317, LAB-1318, LAB-1319, LAB-1320, LAB-1321, and LAB-1322.**
	RESEARCH AND DEVELOPMENT GENERAL SOFTWARE MANAGEMENT Form 414.A86		
1	**Has a description of the software process and requirements been documented?**	**Yes**	**A description of the software process and requirements has been documented by completing form 414.A86.**
2	**Are all interfaces applied to the process identified?**	**Yes**	**All interfaces applied to the process are identified by completing form 414.A86.**

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3	Are outputs from interfaces recorded and reviewed?	Yes	Outputs from interfaces are recorded and reviewed. Verification is recorded in Lab Notebooks. Information is documented in the following Laboratory Notebooks: • LAB-1317 pg. 13-16 • LAB-1318 pg. 16-21 • LAB-1319 pg. 19-23 • LAB-1320 pg. 8-13 • LAB-1321 pg. 12-15 • LAB-1322 pg. 12-15
4	Are all Technical and Functional Requirements identified?	Yes	Technical and Functional Requirements identified in form 414.A86.
5	Has testing of software been done and are the results acceptable?	Yes	Software testing results and acceptance is documented in Laboratory Notebooks. See RESEARCH AND DEVELOPMENT GENERAL SOFTWARE MANAGEMENT #3.
6	Has results of the testing been recorded and documented?	Yes	Software results and acceptance is documented in Laboratory Notebooks. See RESEARCH AND DEVELOPMENT GENERAL SOFTWARE MANAGEMENT #3.
7	Have modifications to any part of the process of software been made? If so has the modifications been recorded and documented?	N/A	There are no modifications to software at this time.
	LABORATORY INSTRUCTIONS		
1	Has a valid Laboratory Instruction for general work control been completed and does it appropriately mitigate all hazards associated to personnel? LWP-21220	Yes	A Laboratory Instruction (LI) has been written and addresses all hazards associated to personnel.

This form is used with LWP-13740, "Performing Inspections."

Note	It should be noted that an approved test plan is not part of this assessment. It should also be noted that the personnel performing this work are progressing toward getting a test plan in place ahead of schedule.		

INSPECTION REPORT
IAS081221 NGNP Work Control Surveillance for Cold Characterization of Graphite

Item Nos. (Referenced from table above)	**Issues/Observations Identified** (Analyze results and identify problems or situations, positive or negative, that should be brought to management's attention.)	**Issue/Observation Disposition** (ICARE, Other)
N/A	N/A	N/A
N/A	**Assessment dates 1/2909-2/18/09**	N/A

2/18/09
2/18/09

Person Leading Inspection Signature ______ Date ______

Cognizant Director/Manager Signature ______ 2/18/09 Date

Assurance Coordinator Use Only

Date received: ______ Entered into IAS database by: ______ Issue(s)/observation(s) disposition verified by: ______ Date ______

This form is used with LWP-13740, "Performing Inspections."

INSPECTION REPORT
IAS081221 NGNP Work Control Surveillance for Cold Characterization of Graphite

INSTRUCTIONS FOR COMPLETION OF FORM 220.23

Integrated Assessment System (IAS) No.: Enter the inspection number provided by the Integrated Assessment System or contract the organizational Assurance Coordinator for a number.

Cognizant director/manager: Enter the name of the sponsoring director or manager.

Inspection title: Provide a title that reflects the purpose and scope of the inspection.

Personnel performing inspection and assigned topic: Identify the team members, including the lead, and the topics they are qualified to assess and responsible for evaluating.

Purpose and scope: Describe the purpose of the inspection. Purpose provides the reason or objectives for "why" the inspection is being performed. Describe the scope of the inspection. Scope provides the boundaries within which the inspection activity is be performed. Scope should include the "what," "where," and "depth" of the inspection.

Organization(s)/program(s)/facilities to be evaluated: Identify the organization number(s) and title(s), programs, and/or facilities that are the subject of the inspection.

Procedures and/or other documents used to evaluate conditions during inspections: Identified by applicable number, title, and revision of the documents that are the basis for which conditions will be evaluated.

Inspection date(s): Enter the dates when the inspection will take place.

Shift: Enter the shift the inspection will occur.

Manager's concurrence on inspection plan and checklist: Obtain the manager(s) of the inspected organization concurrence of the inspection plan.

Item no. Sequential numbering of the items or criteria to be inspected:

Items to be Inspected and expected condition: Provide the performance criteria that will be used for inspection including topic, reference to requirement or expectation, and method used to evaluate the condition or detailed process work.

Criteria met: Based on evaluation of the expected condition compared to actual condition or performance, indicate "YES" or "NO" if the condition meets the performance requirements or expectations.

Results: Provide a narrative of the conditions observed and/or documents reviewed. Provide an explanation when the performance criterion was NOT satisfied in enough detail that the responsible manager can determine appropriate corrective action.

Item No(s): Sequential numbering of the problems or situations, positive or negative, that should be brought to management's attention for resolution.

Issues/observations identified: Describe problems or situations, positive or negative, that should be brought to management's attention. Document the specific details of the potential issue or observation in clear, factual, and precise wording.

Issue/observation disposition: If known, identify the appropriate disposition of the issue or observation. If unknown, the manager and/or assurance coordinator can assist with this determination.

Person leading inspection: Signature of the employee leading the inspection after factual accuracy of the results has been provided by the assessed organization(s).

Cognizant director/manager: Sponsoring director's or manager's signature. Signature indicates that the manager has reviewed the inspection and concurs that it is factually accurate and satisfies the purpose and scope of the inspection.

Assurance Coordinator Use Only

Date received: The date the inspection was received by the assurance coordinator.

Entered into IAS database by: The signature or initials of the assurance coordinator indicating that the Integrated Assessment System (IAS) has been updated with the report date, status, and results of the inspection.

Issue(s)/observation(s) disposition verified by: The signature or initials of the assurance coordinator indicating the all issues, observations, and noteworthy practices have been dispositioned appropriately and in accordance with LWP-13840, "Corrective Action System," or LWP 13850, "Processing Lessons Learned and Operating Experience Information."

Date: Date assurance coordinator completed the entry into the IAS database and verified disposition of issues, observations, and noteworthy practices.

This form is used with LWP-13740, "Performing Inspections."

Appendix B

Data Illustrating Readiness

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Appendix B

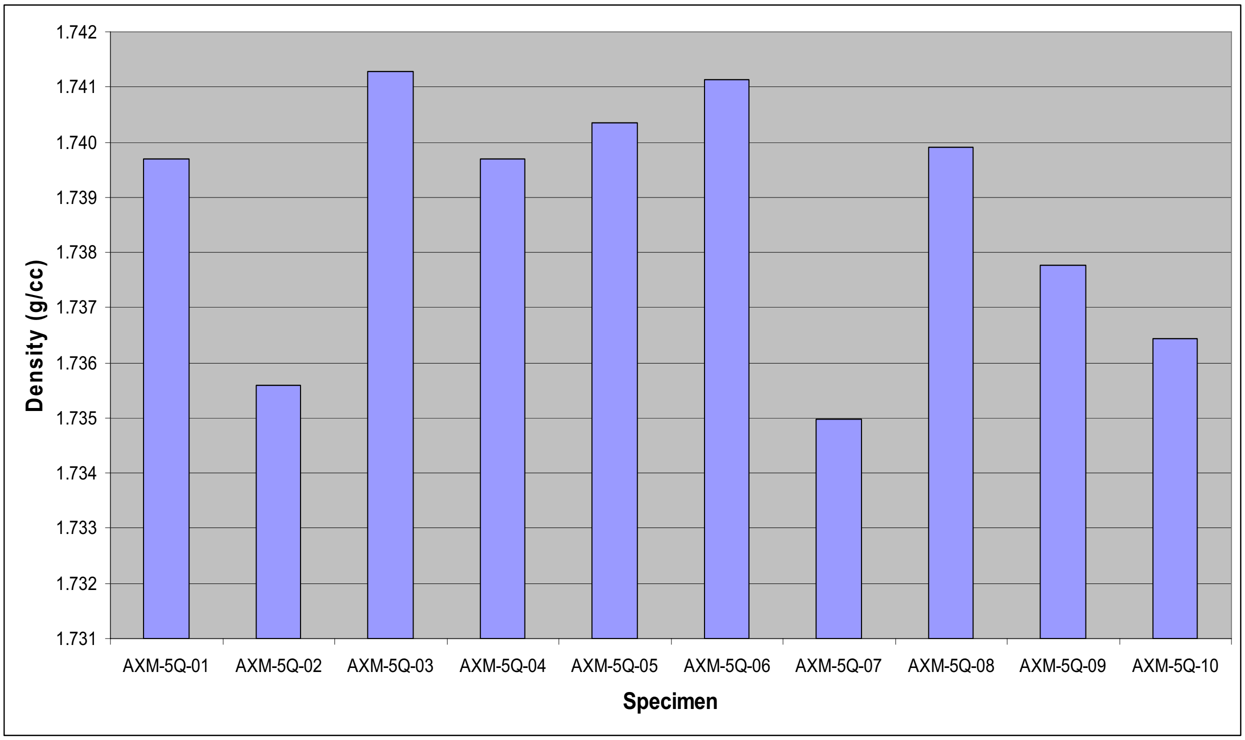
Data Illustrating Readiness

A "dress rehearsal" of all measurements was performed to demonstrate that instrumentation and methods are ready for preirradiation measurement of AGC-2 specimens. Five specimens of Poco AXM-5Q graphite were machined to a 0.5 in. diameter × 1.0 in long, matching the dimensions of the AGC-2 creep sample geometry. These specimens, labeled AXM-5Q-01 through -05, were characterized at all measurement stations with the exception of the thermal diffusivity. Due to the geometrical constraints of the LFA thermal diffusivity measurement, another five specimens were machined to 0.5 in. diameter × 0.25 in. long. These specimens, numbered AXM-5Q-06 through -10, match the AGC-2 piggy-back geometry and were used in the LFA thermal diffusivity demonstration. Table B-1 summarizes the demonstration measurements. The measurement precision is good with all having a coefficient of variation (CV) less than 1%, with the exception of the elastic modulus, calculated from the fundamental frequency, which has a CV of 2%.

Table B-1. Summary of demonstration measurements.

Specimen	AXM-5Q-01	AXM-5Q-02	AXM-5Q-03	AXM-5Q-04	AXM-5Q-05	Coefficient of Variation (%)
Density (g/cc)	1.740	1.736	1.741	1.740	1.740	0.13
CTE (1/°K)	7.680E-06	7.645E-06	7.636E-06	7.723E-06	7.632E-06	0.50
Elastic modulus, (sonic velocity) (Pa)	1.280E+10	1.253E+10	1.278E+10	1.281E+10	1.280E+10	0.94
Elastic modulus, fundamental frequency [Pa]	1.244E+10	1.206E+10	1.238E+10	1.219E+10	1.184E+10	2.01
Electrical resistivity (µOhm/m)	1.523E+01	1.512E+01	1.506E+01	1.512E+01	1.506E+01	0.44
Specimen	**AXM-5Q-06**	**AXM-5Q-07**	**AXM-5Q-08**	**AXM-5Q-09**	**AXM-5Q-10**	**Coefficient of Variation (%)**
Density (g/cc)	1.741	1.735	1.740	1.738	1.736	0.14
Diffusivity (mm^2/s)	25.130	25.307	25.304	24.927	24.941	0.74

The pages that follow contain raw data samples from each measurement.


1.742
1.741
1.740
1.739
1.738
1.737
1.736
1.735
1.734
1.733
1.732
1.731
Density (g/cc)
AXM-5Q-01
AXM-5Q-02
AXM-5Q-03
AXM-5Q-04
AXM-5Q-05
AXM-5Q-06
AXM-5Q-07
AXM-5Q-08
AXM-5Q-09
AXM-5Q-10
Specimen

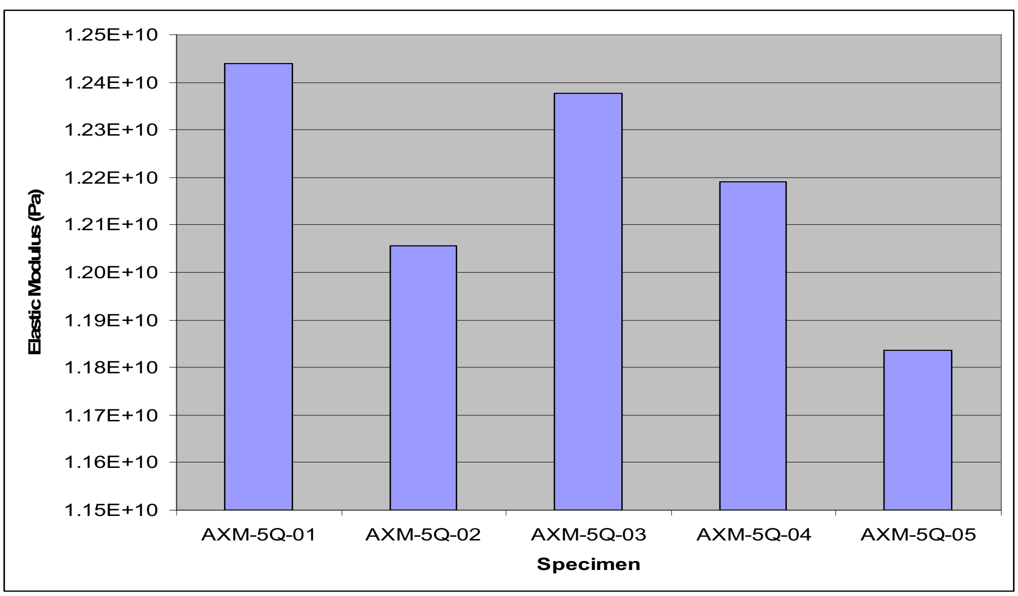
Modulus by Resonant Frequency

Specimen number				AXM-5Q-01	AXM-5Q-02	AXM-5Q-03	AXM-5Q-04	AXM-5Q-05
Date and Time				2/17/2009 13:31	2/17/2009 13:49	2/17/2009 13:55	2/17/2009 13:58	2/17/2009 14:11
Operator				dtr	dtr	dtr	dtr	dtr
Sample location								
mass of specimen	m	[g]		5.6264	5.6126	5.6385	5.6029	5.6211
length of specimen	L	[mm]		25.44975	25.45275	25.53200	25.49950	25.47800
diameter of specimen	D	[mm]		12.72013	12.71875	12.70750	12.68113	12.70475
Poisson's ratio	μ			0.1667	0.1667	0.1667	0.1667	
frequency data	f_i		1	32400	32000	32200	32300	31000
(specimen number			2	32400	31800	32300	32300	30900
oriented up in fixture)			3	31500	31300	31500	32300	31300
			4	32400	32300	32300	32300	32300
			5	32400	30300	32200	29500	30400
			6	32400	31900	32200	29600	32000
			7	32400	31900	32300	32300	32300
			8	32400	32000	32200	32300	32300
			9	31500	31700	30300	32300	32300
			10	32400	32300	32000	32300	31400
average resonant frequency	f_{avg}	[Hz]		32220	31750	31950	31750	31620
correction factor for rod		$T_{1'}$		2.105274156	2.10481668	2.096761759	2.095147081	2.06500756
modulus of elasticity **		E		12439685556	12056617580	12376697176	12190187913	11836848208
$T_{1'}$ correction factor				2.277084311	2.276507264	2.266351933	2.264317327	2.228119442
calculation of individual				0.030473207	0.030445675	0.029963177	0.029866972	0.030191861
terms				0.320291243	0.320001863	0.314930527	0.313919363	0.290047144
				2.266153666	2.265581558	2.255513147	2.253495955	2.182117803
resultant $T_{1'}$		$T_{1'}$		2.105274156	2.10481668	2.096761759	2.095147081	2.06500756
modulus of elasticity *	E	[Pa]		1.24E+10	1.21E+10	1.24E+10	1.22E+10	1.18E+10

Average Modulus for specimen group 1.22E+10
Standard deviation 2.19E+08

Environmental Conditions					
Temperature (°C)	22.2 'C	22.2 'C	22.1 'C	22.1 'C	22.3 'C
Barometric Pressure (in of Hg)	24.99 inHg	24.98 inHg	24.98 inHg	24.98 inHg	24.93 inHg
Humidity (%)	19.9 %RH	19.9 %RH	20.2 %RH	20.4 %RH	20.3 %RH

Sampling Plan Layout: 100% sampling, test them all
Instrument: Grindosonic MK5i
ASTM: C 747 - 93 Reapproved 2005
Using Equation 5 & 6 in ASTM C 1259 - 08

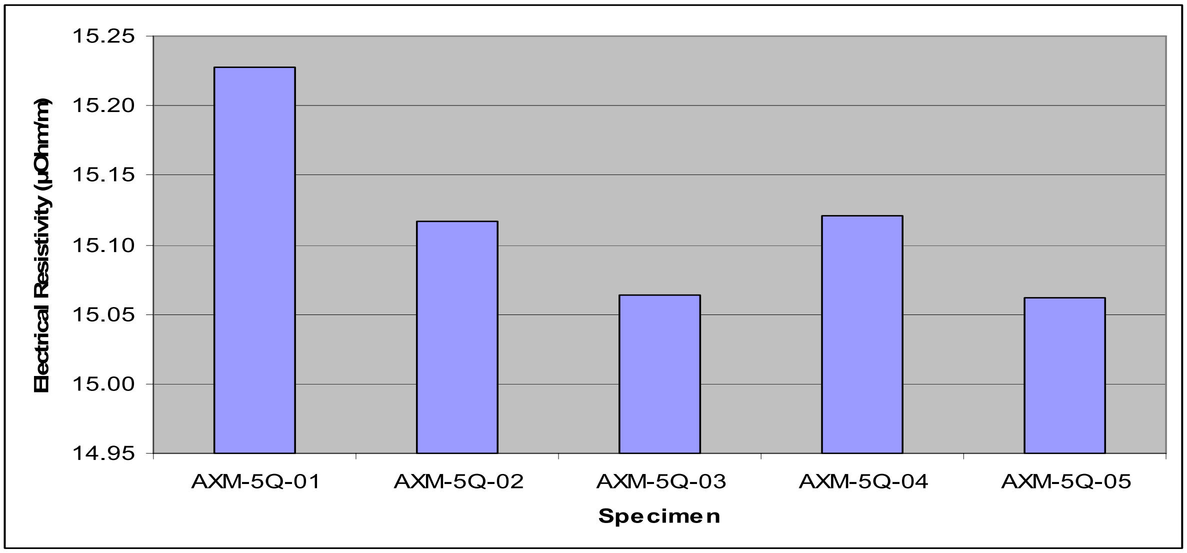


Resistivity

			AXM-5Q-01	AXM-5Q-02	AXM-5Q-03	AXM-5Q-04	AXM-5Q-05
Specimen Number			AXM-5Q-01	AXM-5Q-02	AXM-5Q-03	AXM-5Q-04	AXM-5Q-05
Date and Time			2/17/2009 12:17	2/17/2009 12:24	2/17/2009 12:28	2/17/2009 12:32	2/17/2009 12:35
Operator			dtr	dtr	dtr	dtr	dtr
Sample Location							
Applied current, I	mA		4.0000	4.0000	4.0000	4.0000	4.0000
Compl. Voltage	V		2.5000	2.5000	2.5000	2.5000	2.5000
ID Orientation:							
Forward current:							
Voltage readings, mV		1	0.006141	0.006432	0.006426	0.006496	0.006102
		2	0.006522	0.00618	0.006232	0.006584	0.006259
		3	0.006096	0.006368	0.00629	0.00587	0.006099
		4	0.006113	0.006233	0.006211	0.006019	0.005992
Resistance readings, Ω		1	0.001535	0.001608	0.001607	0.001624	0.001526
		2	0.001631	0.001545	0.001558	0.001646	0.001565
		3	0.001524	0.001592	0.001572	0.001468	0.001525
		4	0.001528	0.001558	0.001553	0.001505	0.001498
Reverse current:							
Voltage readings, mV		1	-0.006015	-0.005245	-0.005757	-0.005953	-0.006073
		2	-0.006254	-0.006168	-0.005696	-0.006351	-0.006084
		3	-0.005802	-0.006041	-0.005752	-0.005649	-0.005782
		4	-0.005792	-0.005779	-0.005969	-0.005654	-0.005903
Resistance readings, Ω		1	0.001504	0.001311	0.001439	0.001488	0.001518
		2	0.001564	0.001542	0.001424	0.001588	0.001521
		3	0.001451	0.00151	0.001438	0.001412	0.001446
		4	0.001448	0.001445	0.001492	0.001414	0.001476
End-for-end orientation:							
Reverse current:							
Voltage readings, mV		1	0.006468	0.006652	0.006601	0.006422	0.006528
		2	0.006444	0.006208	0.006787	0.006374	0.006621
		3	0.00619	0.006128	0.006012	0.006401	0.006127
		4	0.005856	0.005887	0.006028	0.006165	0.00607
Resistance readings, Ω		1	0.001617	0.001663	0.00165	0.001605	0.001632
		2	0.001611	0.001552	0.001697	0.001593	0.001655
		3	0.001548	0.001532	0.001503	0.0016	0.001532
		4	0.001464	0.001472	0.001507	0.001541	0.001517
Forward current:							
Voltage readings, mV		1	-0.005671	-0.00572	-0.005465	-0.005837	-0.005573
		2	-0.006225	-0.006298	-0.006275	-0.005919	-0.00619
		3	-0.005768	-0.005411	-0.005532	-0.005556	-0.005475
		4	-0.006033	-0.005956	-0.005508	-0.006058	-0.005687
Resistance readings, Ω		1	0.001418	0.00143	0.001366	0.001459	0.001393
		2	0.001556	0.001575	0.001569	0.00148	0.001548
		3	0.001442	0.001353	0.001383	0.001389	0.001369
		4	0.001508	0.001489	0.001377	0.001515	0.001422
Average voltage, V	mV		0.006087	0.006044	0.006034	0.006082	0.006035
Average resistance, R=V/I	mΩ		1.521813	1.511063	1.508438	1.520438	1.508938
Potential Contact Distance, L	mm		12.7	12.7	12.7	12.7	12.7
Average area, A mm^2 *	mm^2		127.0787	127.0512	126.8265	126.3006	126.7716
Resistivity, p=(R*A)/L	μΩ/m		15.23	15.12	15.06	15.12	15.06
Environmental Conditions							
Temperature (Deg C)			22.2 'C	22.22 'C	22.2 'C	22.2 'C	22.2 'C
Barometric Pressure (in Hg)			24.96 inHg	24.97 inHg	24.97 inHg	24.97 inHg	24.96 inHg
Humidity (%)			19.9 %RH	19.9 %RH	19/9 %RH	19.9 %RH	19.8 %RH
Other Test Information							
Specimen Orientation			horizontal	horizontal	horizontal	horizontal	horizontal
Method of Measuring Resistance			voltmeter	voltmeter	voltmeter	voltmeter	voltmeter
Probe Location			location	location	location	location	location

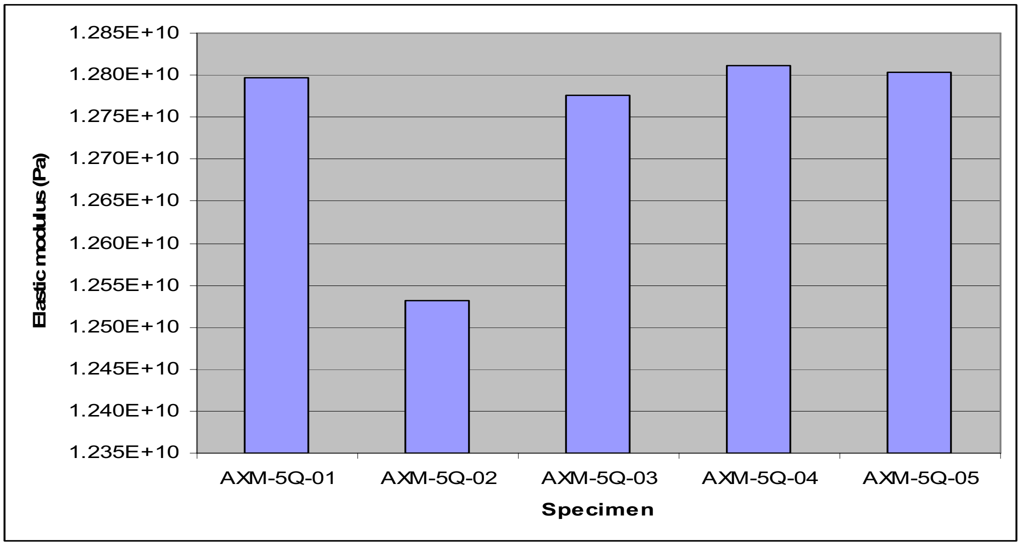
Instruments: Keithley Model 2182 Nanovoltmeter
Keithley Model 6220 DC Current Source

ASTM: C 611 - 98 Reapproved 2005


15.25
15.20
15.15
15.10
15.05
15.00
14.95
Electrical Resistivity (μOhm/m)
AXM-5Q-01
AXM-5Q-02
AXM-5Q-03
AXM-5Q-04
AXM-5Q-05
Specimen

Young's Modulus, Shear Modulus and Poisson's Ratio by Sonic Velocity

Specimen Number	AXM-5Q-01	AXM-5Q-02	AXM-5Q-03	AXM-5Q-04	AXM-5Q-05
Date and Time	2/19/2009 13:33	2/19/2009 13:39	2/19/2009 13:48	2/19/2009 13:58	2/19/2009 14:03
Operator	wds	wds	wds	wds	wds
Specimen Location					
Specimen Length, m	0.02545	0.025453	0.025532	0.0255	0.025478
Density, ρ kg/m^3	1739.6972	1735.5978	1741.2863	1739.6932	1740.3514
Longitudinal Traverse Time, s	8.58E-06	8.56E-06	8.61E-06	8.54E-06	8.58E-06
Shear Traverse Time, s	1.52E-05	1.54E-05	1.52E-05	1.52E-05	1.52E-05
Longitudinal Zero Correction, s	1.89E-07	1.89E-07	1.89E-07	1.89E-07	1.89E-07
Shear Zero Correction, s	2.10E-07	2.10E-07	2.10E-07	2.10E-07	2.10E-07
Sonic Velocities, υ_l (m/s) Longitudinal	3.035E+03	3.041E+03	3.032E+03	3.054E+03	3.037E+03
Sonic Velocities, υ_s (m/s) Shear	1.701E+03	1.679E+03	1.699E+03	1.699E+03	1.701E+03
Elastic Modulus, [Pa] $E=\rho\upsilon_l^2$	1.60228E+10	1.60462E+10	1.60071E+10	1.62209E+10	1.60527E+10
Shear Modulus, [Pa] $G=\rho\upsilon_s^2$	5.035E+09	4.892E+09	5.025E+09	5.021E+09	5.034E+09
Poisson's Ratio $\mu=(1-[2(\upsilon_s/\upsilon_l)^2])/(2-[2(\upsilon_s/\upsilon_l)^2])$	2.709E-01	2.807E-01	2.712E-01	2.758E-01	2.715E-01
Elastic Modulus, [Pa] $E=\rho\upsilon_l^2[(1+\mu)(1-2\mu)/(1-\mu)]$	1.280E+10	1.253E+10	1.278E+10	1.281E+10	1.280E+10
Temperature (Deg C)	21.8 'C	21.8 'C	21.8 'C	21.8 'C	21.8 'C
Pressure (in of Hg)	24.8 inHg	24.8 inHg	24.8 inHg	24.8 inHg	24.8 inHg
Humidity (%)	17.6 %RH	17.6 %RH	17.6 %RH	17.6 %RH	17.6 %RH

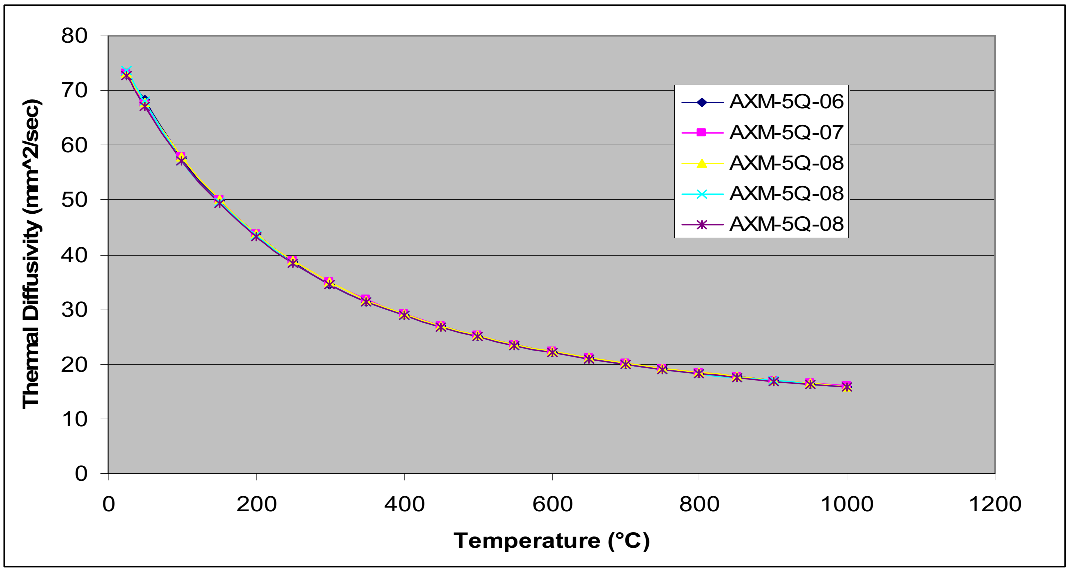


Thermal Diffusivity

##Thermal_diffusivity_Avg

##General_information	
#Database	axm-5q #6 #7 #8.mdb
#Instrument	#LFA_457
#Identity	AXM-5Q #6 #7 #8
#Date/Time	2/5/2009 11:21
#Material	AXM-5Q
#Ref_temperature /°C	23
#Ref_density /(g/cm^3)	1.738
#Sample	AMX-5Q #6,7,8,9,10
#Type	#Single_layer
#Coating	none
#Thickness_RT/mm	6.4017
#Diameter/mm	12.713
#Sensor	InSb
#Beam_enlargement/mm	12.7
#Laser_filter/mm	100
#Atmosphere	Ar
#Gas_flow/(ml/min)	100
#Laboratory	INL
#Operator	dch
#Customer	NGNP
#Remark_mment	AXM-5Q samples #6
#Cp_table	#undefined
#Expansion_table	#undefined
#Temp_recalib_file	Tcalzero.tcx
#Purge_gas	1
#CalcCode	C+p/l/x-x-0

##Results	AXM-5Q-06	AXM-5Q-07	AXM-5Q-08	AXM-5Q-08	AXM-5Q-08
#Temperature (°C)	Diffusivity (mm^2/s)	Diffusivity (mm^2/s)	Diffusivity (mm^2/s)	Diffusivity (mm^2/s)	Diffusivity (mm^2/s)
25	72.928	73.218	73.159	73.608	72.609
50	68.255	67.49	67.872	68.034	67.016
100	57.657	57.837	57.803	57.251	57.154
150	49.827	50.03	50.074	49.645	49.355
200	43.701	43.804	43.879	43.462	43.366
250	38.698	38.833	38.942	38.363	38.412
300	34.649	35	34.947	34.54	34.554
350	31.43	31.738	31.69	31.457	31.357
400	28.932	29.199	29.179	28.932	28.863
450	26.899	27.02	27.006	26.76	26.724
500	25.13	25.307	25.304	24.927	24.941
550	23.558	23.677	23.703	23.443	23.388
600	22.18	22.423	22.315	22.185	22.127
650	21.086	21.227	21.175	21.019	20.964
700	20.042	20.197	20.117	19.989	19.95
750	19.185	19.266	19.277	19.015	19.031
800	18.345	18.452	18.436	18.252	18.205
850	17.647	17.756	17.667	17.572	17.442
900	16.911	17.121	17.068	16.93	16.875
950	16.304	16.418	16.422	16.335	16.301
1000	15.842	15.956	15.724	15.722	15.845



Coefficient of Thermal Expansion

#FILE:	AXM-5Q-01.dle	AXM-5Q-02.dle	AXM-5Q-03.dle	AXM-5Q-04.dle	AXM-5Q-05.dle	AXM-5Q-02 run2.dle
#FORMAT:	NETZSCH5	NETZSCH5	NETZSCH5	NETZSCH5	NETZSCH5	NETZSCH5
#IDENTITY:	AXM-5Q-01	AXM-5Q-02	AXM-5Q-03	AXM-5Q-04	AXM-5Q-05	AXM-5Q-02 run2
#DECIMAL:	POINT	POINT	POINT	POINT	POINT	POINT
#SEPARATOR:	COMMA	COMMA	COMMA	COMMA	COMMA	COMMA
#MTYPE:	DIL	DIL	DIL	DIL	DIL	DIL
#INSTRUMENT:	NETZSCH DIL 402 C	NETZSCH DIL 402 C	NETZSCH DIL 402 C	NETZSCH DIL 402 (	NETZSCH DIL 402	NETZSCH DIL 402 C
#PROJECT:	sapphire	AGC2	AGC2	AGC2	AGC2	AGC2
#DATE/TIME:	2/5/2009 13:57	2/5/2009 13:51	2/6/2009 8:25	2/6/2009 8:20	2/9/2009 8:35	2/9/2009 13:23
#CORR. FILE:	Ne sapp 100_08 3 de	Ne sapp 101_08 3 de	Ne sapp 100_08 3 deg	Ne sapp 101_08 3 d	Ne sapp 100_08 3 (	Ne sapp 101_08 3 deg run2.cle
#LABORATORY:	IRC	INL	IRC	INL	IRC	INL
#OPERATOR:	dch	dch	wds	wds	wds	wds
#REMARK:						
#SAMPLE:	AXM-5Q-01	AXM-5Q-02	AXM-5Q-03	AXM-5Q-04	AXM-5Q-05	AXM-5Q-02 run2
#SAMPLE LENGTH /mr	25.45	25.453	25.532	25.5	25.478	25.453
#MATERIAL:	sapphire	sapphire	graphite	graphite	graphite	graphite
#MEASMODE:	Standard Expansion	Standard Expansion	Standard Expansion	Standard Expansion	Standard Expansior	Standard Expansion
#PURGE GAS 1:	argon	Ar	argon	Ar	argon	Ar
#FLOW RATE 1 /(ml/mi	60	60	60	60	60	60
#CORR. CODE:	0	0	0	0	0	0
#RANGE:	30.0/3.0(K/min)/1040.	30.0/3.0(K/min)/1040.	30.0/3.0(K/min)/1040.(	30.0/3.0(K/min)/104(	30.0/3.0(K/min)/104	30.0/3.0(K/min)/1040.0
#SEGMENT:	S3/3	S3/3	S3/3	S3/3	S3/3	S3/3

	AXM-5Q-01	AXM-5Q-02	AXM-5Q-03	AXM-5Q-04	AXM-5Q-05	AXM-5Q-02 run2
##Temp. /øC	T. Alpha/(1/K)	T. Alpha/(1/K)	T. Alpha/(1/K)	T. Alpha/(1/K)	T. Alpha/(1/K)	T. Alpha/(1/K)
100	7.25E-06	6.98E-06	7.21E-06	7.15E-06	7.22E-06	7.04E-06
200	7.23E-06	7.08E-06	7.21E-06	7.22E-06	7.23E-06	7.11E-06
300	7.37E-06	7.29E-06	7.35E-06	7.40E-06	7.36E-06	7.30E-06
400	7.58E-06	7.50E-06	7.52E-06	7.58E-06	7.52E-06	7.48E-06
500	7.68E-06	7.65E-06	7.64E-06	7.72E-06	7.63E-06	7.63E-06
600	7.78E-06	7.76E-06	7.74E-06	7.82E-06	7.73E-06	7.74E-06
700	7.86E-06	7.90E-06	7.82E-06	7.93E-06	7.82E-06	7.86E-06
800	7.94E-06	8.01E-06	7.88E-06	8.04E-06	7.89E-06	7.98E-06
900	8.02E-06	8.11E-06	7.95E-06	8.13E-06	7.97E-06	8.07E-06
1000	8.10E-06	8.19E-06	8.04E-06	8.22E-06	8.06E-06	8.16E-06