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AGC-3 Specimen Position Calculations by Stack

David T Rohrbaugh

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ENGINEERING CALCULATIONS AND ANALYSIS

Title: AGC-3 Specimen Position Calculations by Stack

ECAR No.: 4430 Rev. No.: 0 Project No.: 29412 Date: 06/11/2019

SIGNATURES

SIGNATURES

	(Name)	(Organization)	(Signature)	(Date)
Performer:	David Rohrbaugh	D520		5/22/2019
Checker[1]:	W. D. Swank	B120		6/11/19
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CUI Reviewer: Yes ☐ or No[5] ☐	N/A			
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Nuclear Safety[4]:	N/A			
Cognizant Engineer[4]:	N/A			
Quality Assurance:	Michelle T. Sharp	H330/C020		6/11/19

1. Confirmation of completeness, mathematical accuracy, and correctness of data and appropriateness of assumptions.
2. Concurrence of method or approach. See definition, LWP-10106.
3. Concurrence of procedure compliance. Concurrence with method/approach and conclusion.
4. Concurrence with the document's assumptions and input information. See definition of Acceptance, LWP-10200.
5. Does the document contain CUI material please check either yes or no.

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Manual: NGNP

REVISION LOG

Rev.	Date	Affected Pages	Revision Description
0	06/11/2019	All	New document.

Title: AGC-3 Specimen Position Calculations by Stack

ECAR No.: 4430 Rev. No.: 0 Project No.: 29412 Date: 06/11/2019

		Professional Engineer's Stamp
1. Does this ECAR involve a Safety SSC?	No	See LWP-10010 for requirements.
2. Safety SSC Determination Document ID	NA	
3. Engineering Job (EJ) No.	NA	
4. SSC ID	NA	
5. Building	NA	
6. Site Area	NA	

7. Objective/Purpose:

This engineering calculations and analysis report documents the specimen position/elevation adjustments from the third capsule of the Advanced Graphite Creep experiment (AGC-3). These adjustments are necessary due to irradiation-induced shrinkage and load-induced creep which can influence the received dose level of the specimens. These effects are calculated and integrated into a table that lists the specimen IDs, their stack number(s), their nominal elevation(s), and the average specimen elevation for each reactor cycle.

8. If revision, please state the reason and list sections and/or pages being affected:

NA

9. Conclusions/Recommendations (Note: Clearly state any actions or additional reviews that were identified within the body of the report):

The position data for all specimens from the AGC-3 capsule were analyzed. Quantification of the amount of downward movement for each specimen is necessary to make accurate dose calculations. The shifting of the specimens is due to irradiation-induced shrinkage and load-induced creep. These effects are calculated and compiled into a table (see Appendix A) that lists the specimen IDs, their stack number(s), their nominal elevation(s), and the estimated specimen elevation for each reactor cycle at the mid-cycle power. Position estimates for the compressed specimens furthest from the core center line moved as much as 0.84 in., which equated to an 11% change in dose, while compressed specimens that were closest to the core center line moved as much as 0.449 in., which equated to a 0.2% change in dose.

CONTENTS

Title: AGC-3 Specimen Position Calculations by Stack

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PROJECT ROLES AND RESPONSIBILITIES

Project Role	Name (Typed)	Organization	Pages covered (if applicable)
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Independent Reviewer[b]	N/A		
CUI Reviewer[c] INL/MIS-19-53379	John T. Major II	M310	All
Manager[d]	Scott McBride	D520	All
Requestor[e]	William Windes	B120	All
Nuclear Safety[e]	N/A		
Document Owner[e]	William Windes	B120	All

Responsibilities:

a. Confirmation of completeness, mathematical accuracy, and correctness of data and appropriateness of assumptions.

b. Concurrence of method or approach. See definition, LWP-10106.

c. Concurrence with the document's markings in accordance with LWP-11202.

d. Concurrence of procedure compliance. Concurrence with method/approach and conclusion.

e. Concurrence with the document's assumptions and input information. See definition of Acceptance, LWP-10200.

NOTE: *Delete or mark "N/A" for project roles not engaged. Include ALL personnel and their roles listed above in the eCR system. The list of the roles above is not all inclusive. If needed, the list can be extended or reduced.*

SCOPE AND BRIEF DESCRIPTION

This engineering calculations and analysis report documents the specimen position/elevation adjustments from the third capsule of the Advanced Graphite Creep experiment (AGC-3). During irradiation the graphite specimens are subjected to both irradiation-induced shrinkage and load-induced creep. Because the specimens are stacked end-to-end within each channel the entire specimen stack will shrink during irradiation and each specimen's elevation will continuously change. These adjustments to the specimen position within the capsule will improve the accuracy of the estimated specimen dose.

The AGC-3 specimens were irradiated in the Advanced Test Reactor (ATR) during Cycles 152B, 154B, 155A, and 155B (the AGC-3 capsule was not in ATR for Cycles 153A/B and 154A). During the course of the irradiation, the graphite specimens shrink as a result of neutron damage. This shrinkage causes all specimens in the capsule to move downward. Along with the irradiation-induced shrinkage in the lower specimen stack, specimens located in the upper loaded stacks were subjected to a compressive load that causes load-induced dimensional change of the upper specimen stack and lower load supporting specimen housing.

Two methods were considered in this analysis to estimate the average position of the specimens during each cycle of irradiation. The first method considered was to estimate the change in length of the lower housing experienced during irradiation. The lower housing supports the upper, compressed specimens, and therefore experiences shrinkage due to irradiation creep. By knowing how much the lower housing shrunk along with the pre- and post-irradiation measurements of the specimens, an estimate of the change in position of the specimens in the upper loaded stacks can be made. There are two issues with this method. The first is that the lengths of the specimen support components were not measured accurately post-irradiation, while the other is that these stressed components are fabricated from NBG-25 graphite, which is a grade that lacks available data for estimating the loaded dimensional change, or creep, of the lower housing.

The second method considered, and the method applied in this analysis, was to use the data from the radiation-resistant linear variable differential transducers (LVDT). Six LVDTs were situated at the top of the pushrods on each compressed stack of specimens. It is important to note that the LVDTs and pushrods are located in a very low dose position, and therefore the effects due to irradiation on both is negligible. The total displacement at the top of each pushrod was measured directly using the LVDT data. Knowing the pre- and post-irradiation dimensions of individual specimens in the upper housing and the total displacement measured by the LVDT allows the creep displacement of the lower housing to be determined. An estimate of the individual specimen positions in the upper housing can be made from the pre- and post-dimensional measurements of the loaded specimens and the creep shrinkage of the lower housing. An estimate of the lower housing unloaded specimens can be made from just the pre- and post-measurements of the individual specimens.

The LVDT data was recorded in 1-minute intervals and eventually archived in the Nuclear Data Management and Analysis System (NDMAS). A plot of the LVDT data as a function of cumulative reactor power during the above reactor cycles is shown in Figure 1. Using the LVDT data, estimates of the position of the loaded specimens were made at the mid-point (with respect to mega-watt days) of each cycle.

Since the specimens located in the lower portions of Stacks 1–6 and all of the specimens in Stack 7 were not compressed, they did not move as much as the specimens in the upper housing. They also did not have any LVDT data to measure their displacement during the experiment. The positions of these specimens were calculated by using pre- and post-irradiation dimensional measurements only.

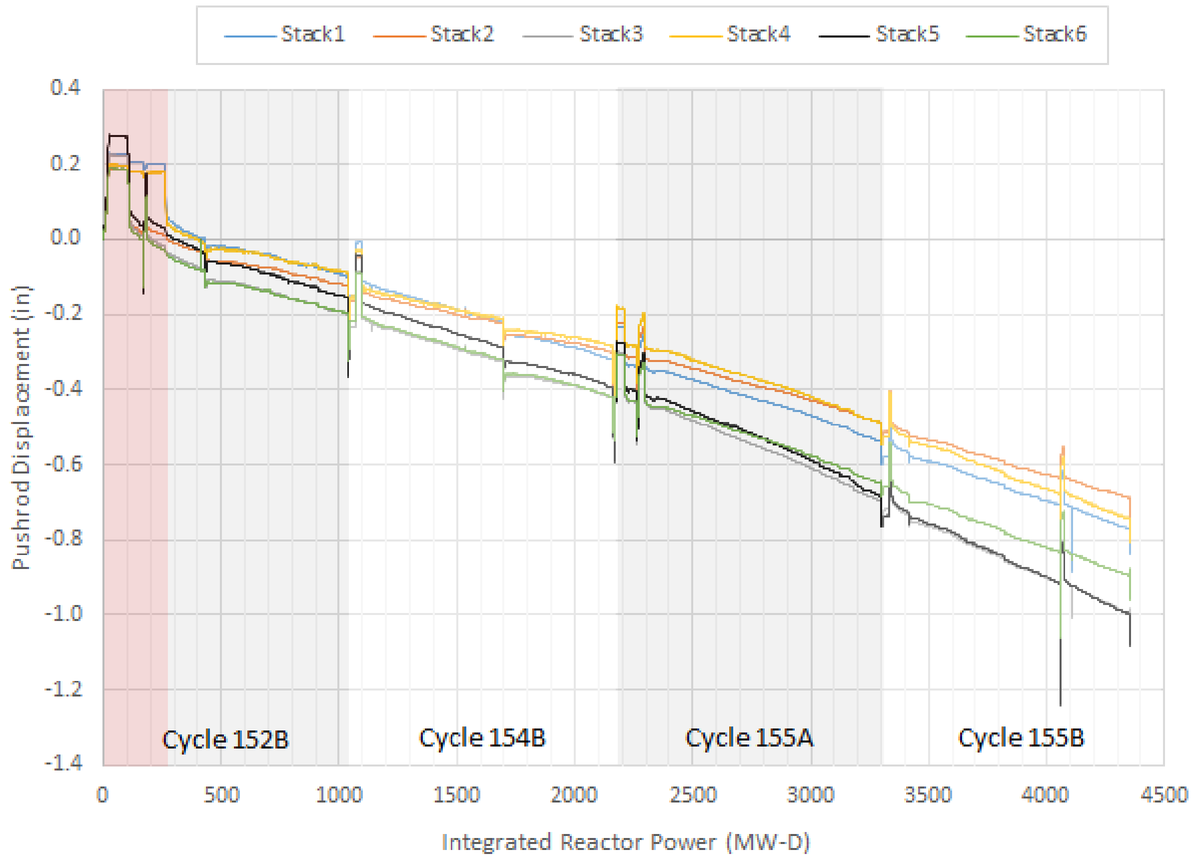

Figure 1. Top of pushrod displacements during the irradiation of AGC-3.

DESIGN OR TECHNICAL PARAMETER INPUT AND SOURCES

Power, displacement, and load data were obtained from NDMAS from ATR starting at Cycle 152B (Nov. 28, 2012) and ending at Cycle 155B (April 12, 2014).

The linearity of the position sensors that were used for this experiment was 0.25% of full scale. The full scale for this model is ± 10 inches, thus the linearity is ± 0.025 inches. During the assembly of the experiment, these LVDTs were verified by Quality Assurance to be calibrated (Engineering Work Instructions for Assembling the AGC-3 Experiment[1]). Table 1 provides the position instrumentation information for the experiment.

Table 1. Position instrumentation.

Instrument	Manufacturer	Model/ Part No.	Accuracy or Linearity	Repeatability
Position Sensor (LVDT)	Macro Sensors	PRH 812-1000-080	≤ ±0.25% of full range output	<0.01% of full scale output

RESULTS OF LITERATURE SEARCHES AND OTHER BACKGROUND DATA

N/A

ASSUMPTIONS

For this analysis, it was assumed that the specimens in each stack did not become lodged or stuck in a position that would alter the LVDT readings for the remainder of the specimens in the stack. To help prevent this from happening, during reactor outages, the compressive loads were removed from the specimen stacks and each graphite stack was raised vertically via the use of lower pneumatic rams. Stack raising was performed at the end of Cycle 152B, between Cycles 154B and 155A, and at the end of Cycle 155B (which was the end of the capsule irradiation). No evidence of sticking was observed during any of those events.[2,3] In addition, the position of each stack remained unaffected between cycles, as observed from Figure 1.

The condition of the position sensors was checked during the assembly of the compressive load control system by performing wire-to-wire resistance checks. The LVDT resistance values were measured and recorded for both the excitation and signal lines.[3] It was impossible to make similar checks on the position system after the completion of the experiment due to disassembly actions and high levels of radiation; however, the position data are consistent within itself indicating that the LVDTs operated properly for the entire experiment.

Since there was no position data measuring specimen displacement for Stack 7 and the lower portions of Stacks 1–6, only pre- and post-irradiation dimensional measurements were used to calculate the displacement of the specimens.

It was assumed that the compressed specimens and the compressed lower housing shrunk linearly with respect to position and reactor integrated power. This is a reasonable assumption based upon the received dose levels of the NBG-25 graphite housing.

Dimensional measurements were not performed on the flux monitor holders (CANs) that were located in the uncompressed stacks. These CANs are made of NBG-25, which is similar to IG-110 in grain size, forming process, and coke source.[4] Therefore, estimates of the dimensional changes of the CANs were made using IG-110 data.

As documented in INL/EXT-14-32425, “AGC-3 Experiment Irradiation Monitoring Data Qualification Final Report,”[3] the initial specimen elevations listed in the experiment assembly documents do not accurately represent the actual specimen positions in relation to the reactor core mid-plane. The heights of the specimens in relation to the core mid-plane are 0.313 in. higher than the nominal dimensions. Thus, the position of all specimens in the capsule are initially increased by this amount.

COMPUTER CODE VALIDATION

Excel software results were validated by random hand calculation checks performed by the checker as allowed per LWP-10200, Appendix E.[5]

DISCUSSION/ANALYSIS

For the specimens located in the compressed portions of the stacks, time, power, load, and displacement data were obtained from NDMAS. The LVDT data were used to estimate the compressed specimen's position throughout the irradiation process. These data were recorded in 1-minute increments. The data were then subsequently reduced to 10-minute increments by averaging. Following the averaging, the position data were plotted and inspected for abnormalities. The first 265 megawatt-days of the irradiation, highlighted in Figure 1 (see the light red region), show extreme instability in the LVDTs. This is due to a gas leak that occurred in the compressive load system, as documented in TFR-510, "Advanced Graphite Capsule Compressive Load Control Gas System."[2] In order to troubleshoot the leak, the loads on the stacks were lifted and adjusted a few times, thereby causing the LVDT readings to fluctuate. This initial troubleshooting period takes place just as the specimens are beginning to receive a neutron dose and is only 6% of the total irradiation time. Therefore, these data were ignored for this analysis.

Also noted is that approximately midway through Cycle 152B, Stack 5 LVDT starts to diverge from Stack 2 LVDT. These two LVDTs should track similarly since they have the same applied load and a similar distribution of specimens by grade. By the end of the irradiation, Stack 5 LVDT has displacement values larger than that of Stack 6, which had the highest applied load. Thus, it is assumed that Stack 5 LVDT displacement readings are suspect during the entire AGC-3 irradiation. To verify this assumption, the total specimen shrinkage (the sum of the change in specimen lengths) for each stack of specimens was calculated and plotted, Figure 2. Contrary to the LVDT data, this plot shows that Stack 5 and Stack 2 had very similar total shrinkage values. This confirms the assumption that the LVDT displacement measurements on Stack 5 were not correct during the irradiation. Thus, the displacement values from Stack 2 LVDT are used as a replacement for the shrinkage values in Stack 5.

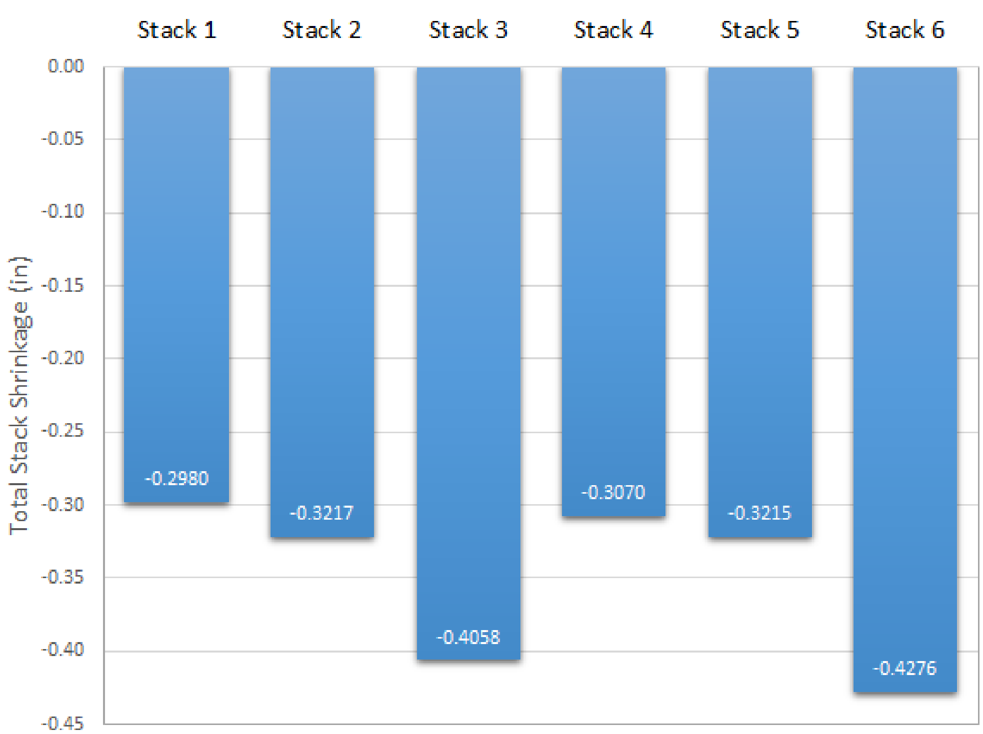

Figure 2. Total specimen shrinkage in the loaded portions of each specimen stack showing that specimens in Stack 2 and Stack 5 had similar dimensional changes.

The position readings for each sensor were adjusted to set the zero position at the first logged data point (after the removal of the first 265 megawatt-days due to pressurization issue with Stack 4). After the initial position is assigned, the LVDT data were broken into four sets, one for each reactor cycle. The mid-point of each cycle was calculated with respect to integrated reactor power. The final displacement value of each specimen stack was taken to be the point right before the loads were removed at the end of the irradiation.

Figure 32 shows the final displacement values for the pushrods on each stack. After discounting Stack 5, Stacks 3 and 6 showed the most displacement, while Stack 2 had the lowest total displacement.

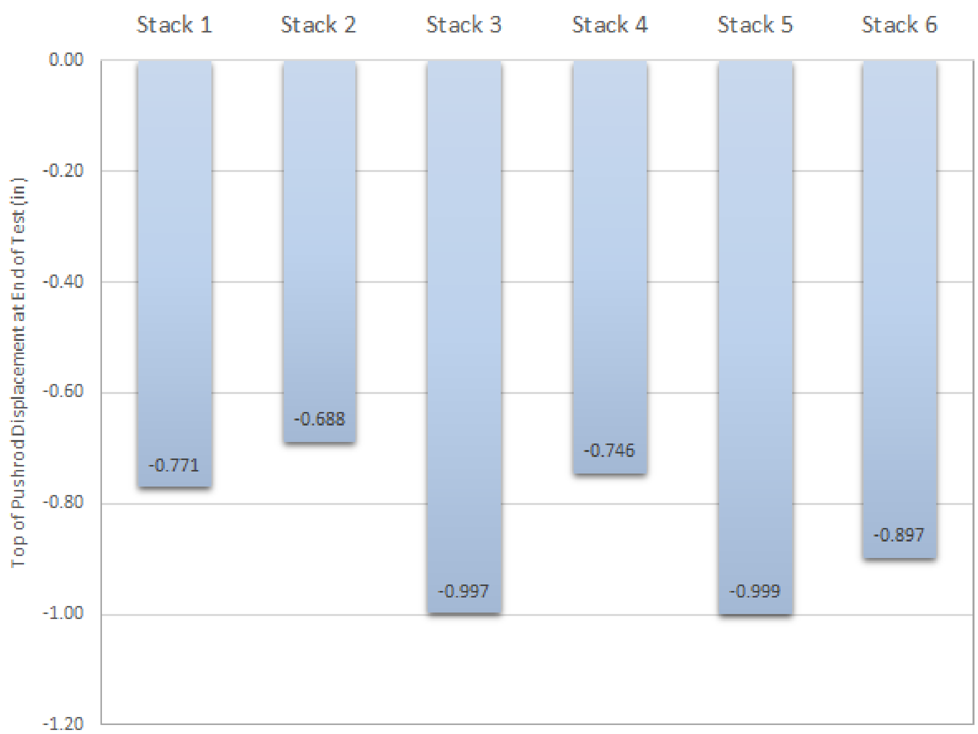

Figure 32. Displacement measured by LVDT on the compressed stacks of specimens during the irradiation of AGC-3 specimens. Note, that Stack 5 displacement was replaced with Stack 2.

The total shrinkage of the lower housing was estimated by using the displacement values from the LVDTs and subtracting the total amount of specimen shrinkage of each stack. These data were then averaged to get a single displacement value for the lower housing. Once the lower housing displacement was estimated, total displacements for each specimen in the loaded stacks were calculated.

Next, for each compressed specimen position in each stack, interpolations were performed between the initial specimen position and the end of test specimen position (calculated above) as a function of integrated reactor power. The positions of all the compressed specimens were then estimated at the middle of each cycle, with respect to integrated reactor power. Figure 3 shows an example of this process for the top specimen (initial center of mass position of 19.813 inches) in Stack 1.

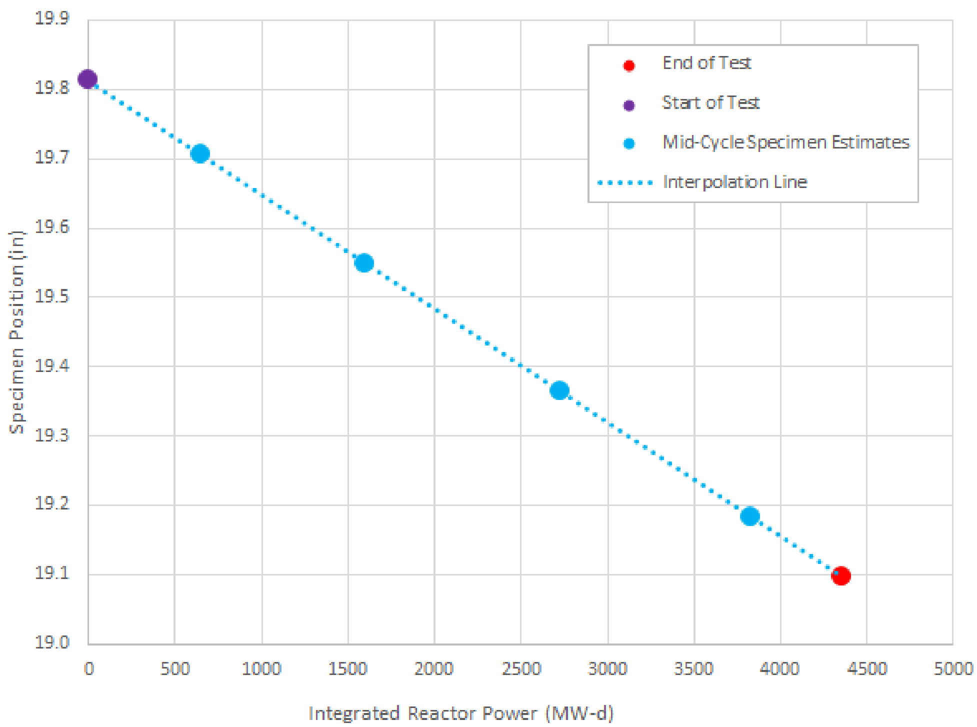

Figure 3. Interpolation of compressed specimen position with respect to integrated reactor power for the top specimen in Stack 1.

The uncompressed specimen's positions (lower portions of Stacks 1–6 and all of Stack 7) were calculated using pre- and post-irradiation dimensional measurements. Figure 4 below shows the total displacement after the irradiation-induced shrinkage for each uncompressed stack. Since the center channel of specimens (Stack 7) extends the full length of the capsule, it had the most overall displacement, while Stack 6 shrunk the least. Interpolations were performed between the initial specimen position and the end of test specimen position as a function of integrated reactor power. The positions of all the uncompressed specimens were then calculated at the middle of each cycle.

Title: AGC-3 Specimen Position Calculations by Stack

ECAR No.: 4430 Rev. No.: 0 Project No.: 29412 Date: 06/11/2019

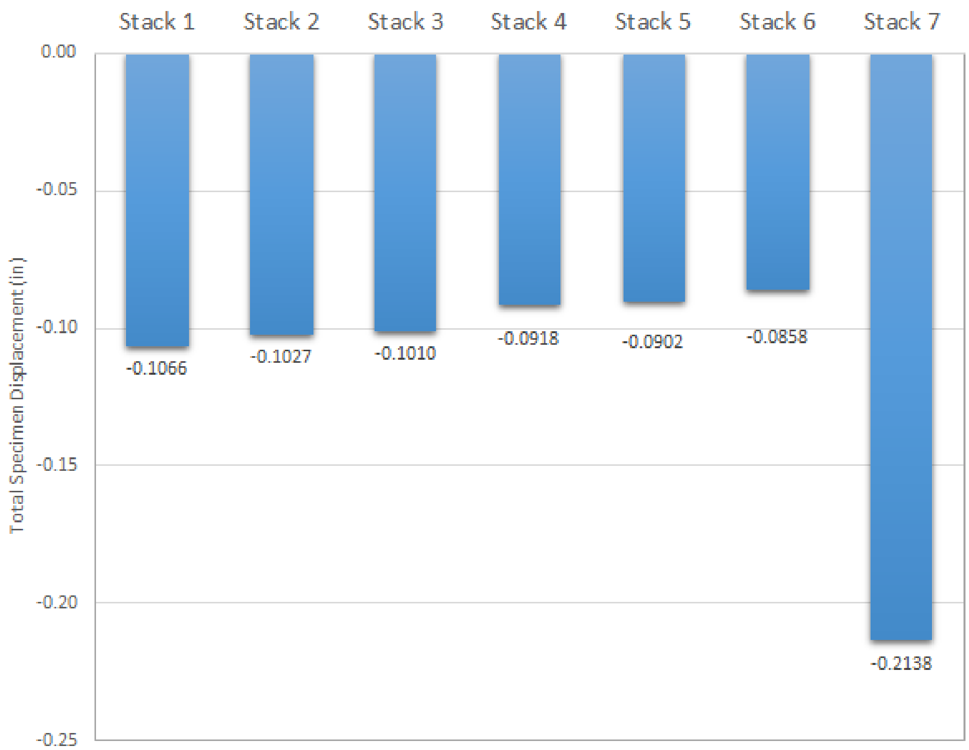

Figure 4. Total stack displacements for the uncompressed specimens in each stack.

SUMMARY AND CONCLUSIONS

The position data from the AGC-3 capsule were analyzed. Quantification of the amount of downward movement for each specimen is necessary to make accurate dose calculations. The shifting of the specimens is due to irradiation-induced shrinkage and load-induced creep. These effects are calculated and compiled into a table (see Appendix A) that lists the specimen IDs, stack number(s), nominal elevation(s), and the estimated specimen elevation for each reactor cycle at mid-cycle power. Position estimates for the compressed specimens furthest from the core center line moved as much as 0.84 in., while compressed specimens that were closest to the core center line moved only 0.449 in. Using ECAR-3051,[6] a summary of the AGC-3 specimen's change in dose with respect to initial position is shown in Figure 5. A shift of 0.84 in., for specimens furthest from the core centerline, corresponds to an 11% change in dose, while a shift of 0.449 in. of the specimens on the core centerline result in a 0.2% change in dose.

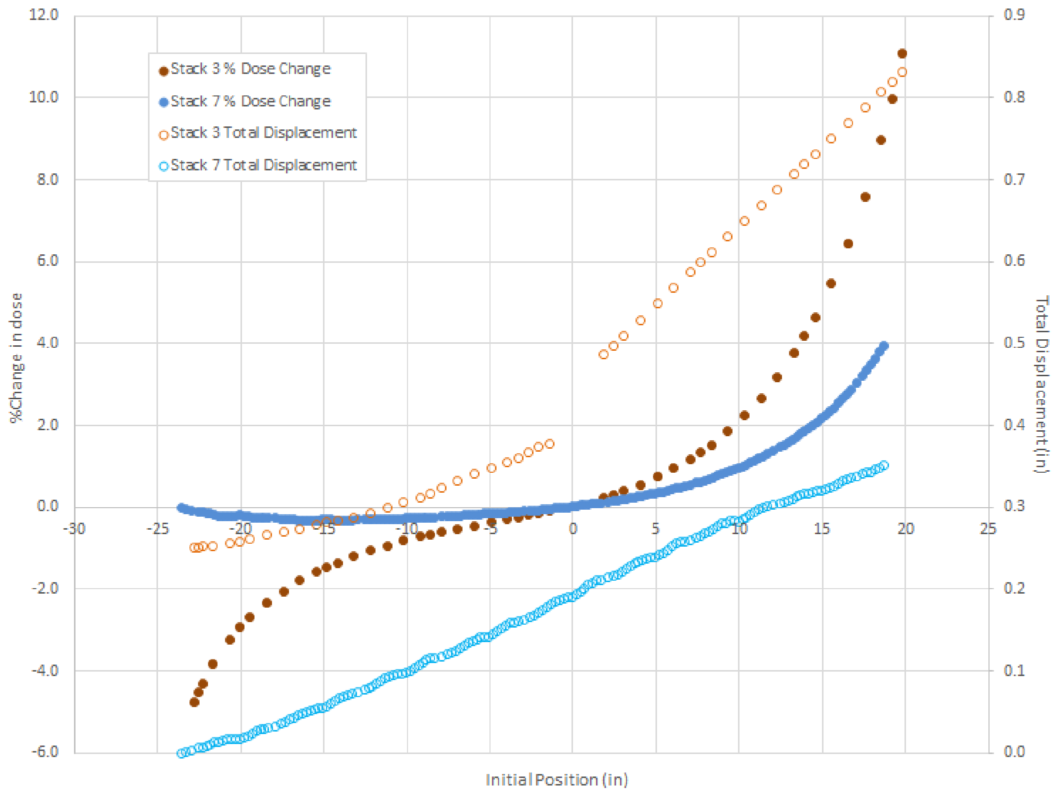

Figure 5. Estimate of the percent change in dose due to specimen shrinkage and total specimen displacement as a function of initial specimen position for specimen Stacks 3 and 7.

REFERENCES

1. WO 159704-01, “Engineering Work Instructions for Assembling the AGC-3 Experiment.”

2. TFR-510, “Advanced Graphite Capsule Compressive Load Control Gas System.”

3. INL/EXT-14-32425, “AGC-3 Experiment Irradiation Monitoring Data Qualification Final Report”, October 2014.

4. Heijna, M. C. R., S. de Groot, J. A. Vreeling, "Comparison of irradiation behaviour of HTR graphite grades," Journal of Nuclear Materials, Vol. 492, 2017.

5. LWP-10200, “Engineering Calculations and Analysis Report,” Rev. 7, April 10, 2012.

6. ECAR-3051, “As-Run Physics Analysis for the AGC-3 Experiment Irradiated in the ATR, February 17, 2016.”

Title: AGC-3 Specimen Position Calculations by Stack

ECAR No.: 4430 Rev. No.: 0 Project No.: 29412 Date: 06/11/2019

Appendix A

Tabulation of Specimen Center of Mass (CoM) Elevations at each Reactor Mid-Cycle

Specimen ID	Stack	Specimen Type	Initial Specimen CoM (in)	152B Mid-Cycle CoM	154B Mid-Cycle CoM	155A Mid-Cycle CoM	155B Mid-Cycle CoM	End of Test CoM
AP3001	1	Stressed Creep	19.813	19.706	19.550	19.364	19.183	19.096
1J	1	Flux Monitor	19.188	19.082	18.928	18.743	18.565	18.479
DW3001	1	Stressed Creep	18.563	18.458	18.304	18.121	17.944	17.858
BW3001	1	Stressed Creep	17.563	17.459	17.308	17.127	16.952	16.868
EW3001	1	Stressed Creep	16.563	16.460	16.311	16.133	15.960	15.876
TW3001	1	Stressed Creep	15.563	15.462	15.315	15.140	14.971	14.889
DW3004	1	Stressed Creep	14.563	14.464	14.319	14.146	13.979	13.899
Y1	1	Flux Monitor	13.938	13.841	13.700	13.532	13.369	13.290
BP3002	1	Stressed Creep	13.313	13.217	13.077	12.909	12.748	12.669
TW3004	1	Stressed Creep	12.313	12.218	12.079	11.914	11.755	11.677
EW3004	1	Stressed Creep	11.313	11.220	11.084	10.922	10.766	10.690
DW3103	1	Stressed Creep	10.313	10.222	10.090	9.933	9.780	9.707
BW3101	1	Stressed Creep	9.313	9.225	9.098	8.945	8.798	8.727
TW3705	1	Stressed Creep	8.313	8.228	8.103	7.955	7.811	7.742
DA	1	Flux Monitor	7.688	7.605	7.484	7.340	7.200	7.132
AP3301	1	Stressed Creep	7.063	6.981	6.860	6.717	6.578	6.511
EW3103	1	Stressed Creep	6.063	5.984	5.868	5.730	5.597	5.533
DW3203	1	Stressed Creep	5.063	4.987	4.876	4.743	4.615	4.553
BL3001	1	Stressed Creep	4.063	3.991	3.885	3.759	3.637	3.579
TW3010	1	Stressed Creep	3.063	2.994	2.892	2.772	2.655	2.598
1L	1	Flux Monitor	2.438	2.371	2.274	2.158	2.045	1.991
AW3103	1	Stressed Creep	1.813	1.747	1.650	1.535	1.424	1.370
TW3605	1	Unstressed control	-1.687	-1.705	-1.732	-1.764	-1.796	-1.811
200-09	1	Piggyback	-2.312	-2.330	-2.356	-2.387	-2.418	-2.432
AW3104	1	Unstressed control	-2.937	-2.954	-2.979	-3.008	-3.037	-3.051
1U	1	Flux Monitor	-3.562	-3.578	-3.601	-3.629	-3.656	-3.669
TW3103	1	Unstressed control	-4.187	-4.202	-4.225	-4.252	-4.278	-4.290
BL3004	1	Unstressed control	-5.187	-5.202	-5.223	-5.248	-5.273	-5.285
DW3302	1	Unstressed control	-6.187	-6.200	-6.220	-6.243	-6.266	-6.277
EW3202	1	Unstressed control	-7.187	-7.199	-7.216	-7.237	-7.257	-7.267
AP3004	1	Unstressed control	-8.187	-8.198	-8.213	-8.232	-8.250	-8.258
AL3804	1	Piggyback	-8.812	-8.822	-8.836	-8.853	-8.869	-8.877
TW3107	1	Unstressed control	-9.437	-9.446	-9.459	-9.475	-9.491	-9.498
BW3501	1	Unstressed control	-10.437	-10.445	-10.457	-10.472	-10.486	-10.493
DW3401	1	Unstressed control	-11.437	-11.444	-11.455	-11.467	-11.479	-11.485
EW3301	1	Unstressed control	-12.437	-12.443	-12.452	-12.462	-12.472	-12.477
TW3201	1	Unstressed control	-13.437	-13.442	-13.450	-13.459	-13.468	-13.473
BP3005	1	Unstressed control	-14.437	-14.442	-14.449	-14.457	-14.465	-14.469
H7	1	Flux Monitor	-15.062	-15.066	-15.073	-15.080	-15.087	-15.091
DW3404	1	Unstressed control	-15.687	-15.691	-15.696	-15.702	-15.709	-15.712
TW3402	1	Unstressed control	-16.687	-16.690	-16.694	-16.699	-16.704	-16.707
EW3304	1	Unstressed control	-17.687	-17.689	-17.693	-17.697	-17.701	-17.703
BW3301	1	Unstressed control	-18.687	-18.689	-18.691	-18.695	-18.698	-18.699
DW3504	1	Unstressed control	-19.687	-19.688	-19.691	-19.693	-19.696	-19.697
F7	1	Flux Monitor	-20.312	-20.313	-20.315	-20.317	-20.319	-20.319
AP3202	1	Unstressed control	-20.937	-20.938	-20.939	-20.940	-20.942	-20.942
TW3608	1	Unstressed control	-21.937	-21.937	-21.938	-21.939	-21.940	-21.940
325-12	1	Piggyback	-22.562	-22.562	-22.563	-22.563	-22.564	-22.564
200-12	1	Piggyback	-22.812	-22.812	-22.813	-22.813	-22.813	-22.813
AL3805	1	Piggyback	-23.062	-23.062	-23.062	-23.062	-23.062	-23.062

Title: AGC-3 Specimen Position Calculations by Stack

ECAR No.: 4430 Rev. No.: 0 Project No.: 29412 Date: 06/11/2019

Specimen ID	Stack	Specimen Type	Initial Specimen CoM (in)	152B Mid-Cycle CoM	154B Mid-Cycle CoM	155A Mid-Cycle CoM	155B Mid-Cycle CoM	End of Test CoM
AP3002	2	Stressed creep	19.813	19.703	19.541	19.349	19.163	19.073
EA-SP1	2	Piggyback	19.188	19.079	18.919	18.730	18.546	18.457
DW3002	2	Stressed creep	18.563	18.454	18.296	18.107	17.924	17.836
BW3002	2	Stressed creep	17.563	17.456	17.300	17.114	16.934	16.846
EW3802	2	Stressed creep	16.563	16.457	16.303	16.119	15.941	15.855
TW3002	2	Stressed creep	15.563	15.459	15.308	15.127	14.952	14.868
DW3101	2	Stressed creep	14.563	14.461	14.312	14.134	13.962	13.878
2B	2	Flux Monitor	13.938	13.838	13.693	13.519	13.351	13.270
BP3003	2	Stressed creep	13.313	13.214	13.069	12.897	12.730	12.649
TW3005	2	Stressed creep	12.313	12.216	12.074	11.905	11.741	11.662
EW3101	2	Stressed creep	11.313	11.218	11.079	10.913	10.753	10.675
DW3201	2	Stressed creep	10.313	10.220	10.085	9.924	9.768	9.693
BW3402	2	Stressed creep	9.313	9.224	9.093	8.938	8.787	8.714
TW3008	2	Stressed creep	8.313	8.226	8.099	7.948	7.802	7.731
EA-SP2	2	Piggyback	7.688	7.604	7.481	7.334	7.192	7.124
AP3302	2	Stressed creep	7.063	6.979	6.857	6.712	6.571	6.503
EW3104	2	Stressed creep	6.063	5.983	5.866	5.726	5.591	5.525
DW3204	2	Stressed creep	5.063	4.986	4.874	4.740	4.611	4.548
BL3002	2	Stressed creep	4.063	3.990	3.884	3.758	3.635	3.576
TW3101	2	Stressed creep	3.063	2.993	2.892	2.771	2.654	2.597
FA	2	Flux Monitor	2.438	2.371	2.274	2.158	2.045	1.991
AW3201	2	Stressed creep	1.813	1.747	1.650	1.535	1.424	1.370
TW3606	2	Unstressed control	-1.687	-1.706	-1.733	-1.766	-1.797	-1.812
200-10	2	Piggyback	-2.312	-2.330	-2.357	-2.388	-2.419	-2.434
AW3202	2	Unstressed control	-2.937	-2.954	-2.979	-3.009	-3.038	-3.052
EA3609	2	Piggyback	-3.562	-3.578	-3.602	-3.629	-3.657	-3.670
TW3105	2	Unstressed control	-4.187	-4.202	-4.225	-4.251	-4.277	-4.290
BL3101	2	Unstressed control	-5.187	-5.201	-5.222	-5.247	-5.272	-5.283
DW3303	2	Unstressed control	-6.187	-6.200	-6.219	-6.242	-6.264	-6.275
EW3203	2	Unstressed control	-7.187	-7.199	-7.216	-7.236	-7.256	-7.266
AP3101	2	Unstressed control	-8.187	-8.197	-8.213	-8.231	-8.249	-8.257
EA3610	2	Piggyback	-8.812	-8.821	-8.835	-8.852	-8.868	-8.875
TW3108	2	Unstressed control	-9.437	-9.446	-9.459	-9.474	-9.489	-9.496
BW3202	2	Unstressed control	-10.437	-10.445	-10.457	-10.471	-10.485	-10.492
DW3402	2	Unstressed control	-11.437	-11.444	-11.455	-11.467	-11.480	-11.485
EW3302	2	Unstressed control	-12.437	-12.443	-12.452	-12.462	-12.473	-12.478
TW3202	2	Unstressed control	-13.437	-13.442	-13.450	-13.459	-13.468	-13.473
BP3101	2	Unstressed control	-14.437	-14.442	-14.449	-14.457	-14.465	-14.469
7O	2	Flux Monitor	-15.062	-15.066	-15.073	-15.081	-15.088	-15.092
DW3501	2	Unstressed control	-15.687	-15.691	-15.697	-15.703	-15.710	-15.713
TW3403	2	Unstressed control	-16.687	-16.690	-16.695	-16.700	-16.705	-16.708
EW3401	2	Unstressed control	-17.687	-17.690	-17.693	-17.698	-17.702	-17.704
BW3503	2	Unstressed control	-18.687	-18.689	-18.692	-18.696	-18.700	-18.702
DW3601	2	Unstressed control	-19.687	-19.689	-19.692	-19.695	-19.698	-19.700
EA3611	2	Piggyback	-20.312	-20.313	-20.315	-20.318	-20.320	-20.321
AP3203	2	Unstressed control	-20.937	-20.938	-20.939	-20.941	-20.942	-20.943
TW3609	2	Unstressed control	-21.937	-21.938	-21.938	-21.939	-21.940	-21.941
325-13	2	Piggyback	-22.562	-22.562	-22.563	-22.564	-22.564	-22.564
200-13	2	Piggyback	-22.812	-22.812	-22.813	-22.813	-22.814	-22.814
AL3806	2	Piggyback	-23.062	-23.062	-23.062	-23.062	-23.062	-23.062

Title: AGC-3 Specimen Position Calculations by Stack

ECAR No.: 4430 Rev. No.: 0 Project No.: 29412 Date: 06/11/2019

Specimen ID	Stack	Specimen Type	Initial Specimen CoM (in)	152B Mid-Cycle CoM	154B Mid-Cycle CoM	155A Mid-Cycle CoM	155B Mid-Cycle CoM	End of Test CoM
AP3003	3	Stressed creep	19.813	19.691	19.513	19.301	19.096	18.997
EW-SP1	3	Piggyback	19.188	19.068	18.892	18.683	18.480	18.383
DW3003	3	Stressed creep	18.563	18.444	18.269	18.061	17.860	17.763
BW3401	3	Stressed creep	17.563	17.446	17.275	17.071	16.873	16.778
EW3003	3	Stressed creep	16.563	16.447	16.279	16.078	15.883	15.789
TW3003	3	Stressed creep	15.563	15.450	15.285	15.088	14.898	14.805
DW3102	3	Stressed creep	14.563	14.452	14.290	14.097	13.910	13.820
AF	3	Flux Monitor	13.938	13.830	13.673	13.485	13.304	13.216
BP3004	3	Stressed creep	13.313	13.206	13.050	12.864	12.684	12.597
TW3006	3	Stressed creep	12.313	12.209	12.058	11.878	11.703	11.619
EW3801	3	Stressed creep	11.313	11.212	11.065	10.889	10.719	10.637
DW3202	3	Stressed creep	10.313	10.215	10.073	9.903	9.739	9.659
BW3103	3	Stressed creep	9.313	9.220	9.083	8.921	8.763	8.687
TW3009	3	Stressed creep	8.313	8.223	8.091	7.934	7.782	7.708
EW-SP2	3	Piggyback	7.688	7.601	7.474	7.322	7.175	7.105
AP3303	3	Stressed creep	7.063	6.977	6.851	6.701	6.555	6.485
EW3201	3	Stressed creep	6.063	5.981	5.860	5.717	5.579	5.511
DW3301	3	Stressed creep	5.063	4.985	4.870	4.734	4.602	4.538
BL3003	3	Stressed creep	4.063	3.990	3.882	3.755	3.631	3.571
TW3102	3	Stressed creep	3.063	2.993	2.891	2.770	2.652	2.596
8I	3	Flux Monitor	2.438	2.372	2.275	2.159	2.047	1.993
AW3203	3	Stressed creep	1.813	1.747	1.652	1.538	1.427	1.374
TW3607	3	Unstressed control	-1.687	-1.706	-1.734	-1.767	-1.799	-1.814
200-11	3	Piggyback	-2.312	-2.330	-2.357	-2.389	-2.421	-2.436
AW3204	3	Unstressed control	-2.937	-2.955	-2.980	-3.011	-3.040	-3.054
EW4607	3	Piggyback	-3.562	-3.578	-3.602	-3.631	-3.658	-3.672
TW3106	3	Unstressed control	-4.187	-4.203	-4.225	-4.253	-4.279	-4.292
BL3102	3	Unstressed control	-5.187	-5.202	-5.223	-5.249	-5.274	-5.286
DW3304	3	Unstressed control	-6.187	-6.201	-6.220	-6.244	-6.267	-6.278
EW3204	3	Unstressed control	-7.187	-7.199	-7.217	-7.238	-7.259	-7.269
AP3102	3	Unstressed control	-8.187	-8.198	-8.214	-8.233	-8.251	-8.260
EW4608	3	Piggyback	-8.812	-8.822	-8.837	-8.854	-8.871	-8.879
TW3109	3	Unstressed control	-9.437	-9.446	-9.460	-9.476	-9.492	-9.499
BW3502	3	Unstressed control	-10.437	-10.445	-10.458	-10.473	-10.487	-10.494
DW3403	3	Unstressed control	-11.437	-11.444	-11.455	-11.468	-11.481	-11.487
EW3303	3	Unstressed control	-12.437	-12.443	-12.453	-12.464	-12.474	-12.480
TW3704	3	Unstressed control	-13.437	-13.443	-13.451	-13.460	-13.470	-13.474
BP3102	3	Unstressed control	-14.437	-14.442	-14.450	-14.458	-14.467	-14.471
XA	3	Flux Monitor	-15.062	-15.067	-15.074	-15.082	-15.090	-15.094
DW3502	3	Unstressed control	-15.687	-15.691	-15.697	-15.705	-15.712	-15.716
TW3404	3	Unstressed control	-16.687	-16.691	-16.696	-16.702	-16.708	-16.711
EW3402	3	Unstressed control	-17.687	-17.690	-17.694	-17.700	-17.705	-17.707
BW3303	3	Unstressed control	-18.687	-18.689	-18.693	-18.697	-18.701	-18.703
DW3602	3	Unstressed control	-19.687	-19.689	-19.691	-19.694	-19.697	-19.699
EW4609	3	Piggyback	-20.312	-20.313	-20.315	-20.317	-20.319	-20.320
AP3204	3	Unstressed control	-20.937	-20.938	-20.939	-20.940	-20.942	-20.942
TW3610	3	Unstressed control	-21.937	-21.938	-21.938	-21.939	-21.940	-21.940
325-14	3	Piggyback	-22.562	-22.562	-22.563	-22.563	-22.564	-22.564
200-14	3	Piggyback	-22.812	-22.812	-22.813	-22.813	-22.814	-22.814
AL3807	3	Piggyback	-23.062	-23.062	-23.062	-23.062	-23.062	-23.062

Title: AGC-3 Specimen Position Calculations by Stack

ECAR No.: 4430 Rev. No.: 0 Project No.: 29412 Date: 06/11/2019

Specimen ID	Stack	Specimen Type	Initial Specimen CoM (in)	152B Mid-Cycle CoM	154B Mid-Cycle CoM	155A Mid-Cycle CoM	155B Mid-Cycle CoM	End of Test CoM
EW3601	4	Stressed creep	19.813	19.703	19.542	19.351	19.165	19.076
7A	4	Flux Monitor	19.188	19.079	18.920	18.731	18.547	18.459
TW3703	4	Stressed creep	18.563	18.455	18.297	18.108	17.926	17.838
DA3001	4	Stressed creep	17.563	17.456	17.300	17.114	16.933	16.846
BP3103	4	Stressed creep	16.563	16.457	16.303	16.120	15.942	15.856
AL3202	4	Stressed creep	15.563	15.459	15.307	15.126	14.950	14.866
EW3604	4	Stressed creep	14.563	14.461	14.311	14.133	13.961	13.878
1H	4	Flux Monitor	13.938	13.838	13.692	13.517	13.349	13.267
DW3801	4	Stressed creep	13.313	13.213	13.068	12.895	12.727	12.646
BL3103	4	Stressed creep	12.313	12.216	12.074	11.905	11.742	11.663
TW3405	4	Stressed creep	11.313	11.218	11.079	10.914	10.754	10.677
AW3001	4	Stressed creep	10.313	10.220	10.085	9.923	9.767	9.692
EA3001	4	Stressed creep	9.313	9.223	9.092	8.935	8.783	8.710
DA3203	4	Stressed creep	8.313	8.226	8.099	7.947	7.801	7.730
YA	4	Flux Monitor	7.688	7.604	7.482	7.336	7.195	7.127
BP3202	4	Stressed creep	7.063	6.980	6.858	6.714	6.574	6.506
TW3408	4	Stressed creep	6.063	5.982	5.865	5.725	5.589	5.524
AP3304	4	Stressed creep	5.063	4.985	4.871	4.735	4.603	4.540
EA3004	4	Stressed creep	4.063	3.988	3.879	3.748	3.622	3.561
DW3603	4	Stressed creep	3.063	2.991	2.887	2.762	2.641	2.583
1C	4	Flux Monitor	2.438	2.370	2.272	2.154	2.040	1.985
BP3301	4	Stressed creep	1.813	1.746	1.648	1.531	1.418	1.364
AW3810	4	Piggyback	-1.312	-1.332	-1.362	-1.397	-1.431	-1.448
EW4601	4	Piggyback	-1.562	-1.582	-1.611	-1.645	-1.678	-1.694
TW3821	4	Piggyback	-1.812	-1.831	-1.859	-1.893	-1.925	-1.941
325-09	4	Piggyback	-2.062	-2.081	-2.109	-2.142	-2.174	-2.189
P3-07	4	Piggyback	-2.312	-2.331	-2.358	-2.391	-2.422	-2.438
BP3304	4	Unstressed control	-2.937	-2.955	-2.982	-3.013	-3.044	-3.059
R7	4	Flux Monitor	-3.562	-3.580	-3.605	-3.636	-3.666	-3.680
DW3702	4	Unstressed control	-4.187	-4.204	-4.228	-4.258	-4.286	-4.300
EA3103	4	Unstressed control	-5.187	-5.202	-5.225	-5.252	-5.278	-5.291
AP3403	4	Unstressed control	-6.187	-6.201	-6.222	-6.246	-6.270	-6.282
TW3501	4	Unstressed control	-7.187	-7.200	-7.219	-7.242	-7.265	-7.275
BP3603	4	Unstressed control	-8.187	-8.199	-8.218	-8.239	-8.260	-8.270
TW3904	4	Piggyback	-8.812	-8.824	-8.841	-8.862	-8.882	-8.891
DA3302	4	Unstressed control	-9.437	-9.448	-9.464	-9.484	-9.502	-9.511
EA3202	4	Unstressed control	-10.437	-10.447	-10.461	-10.478	-10.495	-10.503
AW3004	4	Unstressed control	-11.437	-11.446	-11.458	-11.473	-11.488	-11.495
TW3504	4	Unstressed control	-12.437	-12.445	-12.456	-12.470	-12.483	-12.489
BL3201	4	Unstressed control	-13.437	-13.444	-13.455	-13.467	-13.479	-13.485
DW3803	4	Unstressed control	-14.437	-14.443	-14.453	-14.464	-14.474	-14.479
I0	4	Flux Monitor	-15.062	-15.068	-15.076	-15.086	-15.095	-15.100
EW3403	4	Unstressed control	-15.687	-15.692	-15.700	-15.709	-15.717	-15.722
AL3301	4	Unstressed control	-16.687	-16.691	-16.698	-16.705	-16.712	-16.716
BP3801	4	Unstressed control	-17.687	-17.691	-17.696	-17.702	-17.709	-17.712
DA3403	4	Unstressed control	-18.687	-18.690	-18.695	-18.701	-18.706	-18.709
TW3507	4	Unstressed control	-19.687	-19.690	-19.694	-19.699	-19.704	-19.706
JA	4	Flux Monitor	-20.312	-20.315	-20.318	-20.323	-20.327	-20.329
EW3502	4	Unstressed control	-20.937	-20.939	-20.942	-20.946	-20.950	-20.952
BL3601	4	Piggyback	-21.562	-21.564	-21.566	-21.569	-21.572	-21.574
AL3801	4	Piggyback	-21.812	-21.813	-21.815	-21.818	-21.820	-21.822
EW4509	4	Piggyback	-22.062	-22.063	-22.064	-22.066	-22.068	-22.069
AL3904	4	Piggyback	-22.312	-22.313	-22.313	-22.314	-22.315	-22.316
DW4511	4	Piggyback	-22.562	-22.562	-22.563	-22.564	-22.564	-22.565
DA3510	4	Piggyback	-22.812	-22.812	-22.813	-22.813	-22.814	-22.814
TW3827	4	Piggyback	-23.062	-23.062	-23.062	-23.062	-23.062	-23.062

Title: AGC-3 Specimen Position Calculations by Stack

ECAR No.: 4430 Rev. No.: 0 Project No.: 29412 Date: 06/11/2019

Specimen ID	Stack	Specimen Type	Initial Specimen CoM (in)	152B Mid-Cycle CoM	154B Mid-Cycle CoM	155A Mid-Cycle CoM	155B Mid-Cycle CoM	End of Test CoM
EW3602	5	Stressed creep	19.813	19.701	19.537	19.341	19.152	19.060
DA-SP1	5	Piggyback	19.188	19.077	18.915	18.721	18.534	18.444
TW3702	5	Stressed creep	18.563	18.453	18.291	18.099	17.913	17.824
DA3003	5	Stressed creep	17.563	17.454	17.294	17.105	16.921	16.832
BP3104	5	Stressed creep	16.563	16.455	16.298	16.111	15.930	15.843
AL3203	5	Stressed creep	15.563	15.457	15.302	15.117	14.938	14.852
EW3701	5	Stressed creep	14.563	14.459	14.306	14.125	13.949	13.865
J7	5	Flux Monitor	13.938	13.836	13.687	13.509	13.337	13.254
DW3804	5	Stressed creep	13.313	13.211	13.063	12.887	12.716	12.633
BL3104	5	Stressed creep	12.313	12.214	12.070	11.898	11.732	11.652
TW3406	5	Stressed creep	11.313	11.216	11.075	10.907	10.744	10.666
AW3002	5	Stressed creep	10.313	10.219	10.081	9.916	9.757	9.680
EA3002	5	Stressed creep	9.313	9.221	9.088	8.929	8.775	8.700
DA3204	5	Stressed creep	8.313	8.224	8.095	7.941	7.792	7.720
DA-SP2	5	Piggyback	7.688	7.603	7.478	7.330	7.186	7.116
BP3204	5	Stressed creep	7.063	6.978	6.855	6.708	6.565	6.496
TW3409	5	Stressed creep	6.063	5.981	5.862	5.719	5.581	5.515
AP3401	5	Stressed creep	5.063	4.984	4.868	4.730	4.596	4.532
EA3101	5	Stressed creep	4.063	3.987	3.877	3.745	3.617	3.556
DW3604	5	Stressed creep	3.063	2.991	2.886	2.760	2.639	2.580
O7	5	Flux Monitor	2.438	2.370	2.271	2.154	2.040	1.985
BP3302	5	Stressed creep	1.813	1.746	1.648	1.531	1.418	1.364
AW3811	5	Piggyback	-1.312	-1.334	-1.366	-1.403	-1.440	-1.458
EW4602	5	Piggyback	-1.562	-1.583	-1.614	-1.651	-1.687	-1.704
TW3822	5	Piggyback	-1.812	-1.833	-1.863	-1.899	-1.934	-1.951
325-10	5	Piggyback	-2.062	-2.082	-2.112	-2.148	-2.183	-2.199
P3-08	5	Piggyback	-2.312	-2.332	-2.362	-2.397	-2.431	-2.447
BP3601	5	Unstressed control	-2.937	-2.957	-2.985	-3.019	-3.052	-3.068
DA3603	5	Piggyback	-3.562	-3.581	-3.608	-3.641	-3.673	-3.688
DW3703	5	Unstressed control	-4.187	-4.205	-4.231	-4.262	-4.292	-4.306
EA3104	5	Unstressed control	-5.187	-5.203	-5.227	-5.255	-5.283	-5.296
AP3404	5	Unstressed control	-6.187	-6.202	-6.224	-6.250	-6.275	-6.287
TW3502	5	Unstressed control	-7.187	-7.201	-7.221	-7.246	-7.269	-7.281
BP3604	5	Unstressed control	-8.187	-8.200	-8.219	-8.242	-8.264	-8.275
DA3604	5	Piggyback	-8.812	-8.824	-8.842	-8.864	-8.885	-8.895
DA3303	5	Unstressed control	-9.437	-9.448	-9.465	-9.485	-9.504	-9.513
EA3203	5	Unstressed control	-10.437	-10.447	-10.462	-10.479	-10.496	-10.504
AW3101	5	Unstressed control	-11.437	-11.446	-11.458	-11.474	-11.488	-11.495
TW3505	5	Unstressed control	-12.437	-12.445	-12.456	-12.470	-12.483	-12.489
BL3202	5	Unstressed control	-13.437	-13.444	-13.455	-13.467	-13.479	-13.485
DW3901	5	Unstressed control	-14.437	-14.443	-14.453	-14.464	-14.474	-14.479
Y2	5	Flux Monitor	-15.062	-15.068	-15.076	-15.086	-15.095	-15.100
EW3704	5	Unstressed control	-15.687	-15.692	-15.700	-15.708	-15.717	-15.721
AL3101	5	Unstressed control	-16.687	-16.691	-16.697	-16.705	-16.712	-16.715
BP3702	5	Unstressed control	-17.687	-17.690	-17.695	-17.701	-17.707	-17.710
DA3404	5	Unstressed control	-18.687	-18.690	-18.694	-18.699	-18.704	-18.706
TW3508	5	Unstressed control	-19.687	-19.689	-19.693	-19.697	-19.702	-19.704
DA3605	5	Piggyback	-20.312	-20.314	-20.317	-20.321	-20.325	-20.327
EW3503	5	Unstressed control	-20.937	-20.939	-20.942	-20.945	-20.948	-20.950
BL3602	5	Piggyback	-21.562	-21.564	-21.566	-21.569	-21.571	-21.573
AL3802	5	Piggyback	-21.812	-21.813	-21.815	-21.818	-21.820	-21.821
EW4510	5	Piggyback	-22.062	-22.063	-22.064	-22.066	-22.068	-22.068
AW3902	5	Piggyback	-22.312	-22.313	-22.313	-22.314	-22.315	-22.316
DW4512	5	Piggyback	-22.562	-22.562	-22.563	-22.563	-22.564	-22.564
DA3511	5	Piggyback	-22.812	-22.812	-22.812	-22.813	-22.813	-22.813
TW3828	5	Piggyback	-23.062	-23.062	-23.062	-23.062	-23.062	-23.062

Title: AGC-3 Specimen Position Calculations by Stack

ECAR No.: 4430 Rev. No.: 0 Project No.: 29412 Date: 06/11/2019

Specimen ID	Stack	Specimen Type	Initial Specimen CoM (in)	152B Mid-Cycle CoM	154B Mid-Cycle CoM	155A Mid-Cycle CoM	155B Mid-Cycle CoM	End of Test CoM
EW3603	6	Stressed creep	19.813	19.687	19.504	19.286	19.074	18.972
DA-SP3	6	Piggyback	19.188	19.064	18.883	18.668	18.459	18.358
TW3602	6	Stressed creep	18.563	18.440	18.261	18.047	17.840	17.740
DA3004	6	Stressed creep	17.563	17.442	17.265	17.054	16.850	16.752
BP3201	6	Stressed creep	16.563	16.444	16.271	16.064	15.864	15.767
AL3204	6	Stressed creep	15.563	15.446	15.275	15.072	14.875	14.780
EW3702	6	Stressed creep	14.563	14.449	14.282	14.083	13.891	13.798
AU	6	Flux Monitor	13.938	13.827	13.664	13.471	13.283	13.192
DW3902	6	Stressed creep	13.313	13.202	13.041	12.849	12.663	12.573
BL3204	6	Stressed creep	12.313	12.206	12.050	11.864	11.684	11.597
TW3407	6	Stressed creep	11.313	11.209	11.057	10.876	10.701	10.616
AW3003	6	Stressed creep	10.313	10.212	10.064	9.888	9.718	9.636
EA3003	6	Stressed creep	9.313	9.216	9.074	8.904	8.740	8.661
DA3301	6	Stressed creep	8.313	8.219	8.083	7.920	7.762	7.686
DA-SP4	6	Piggyback	7.688	7.599	7.468	7.313	7.163	7.090
BP3205	6	Stressed creep	7.063	6.975	6.846	6.692	6.543	6.471
TW3410	6	Stressed creep	6.063	5.978	5.854	5.707	5.564	5.495
AP3402	6	Stressed creep	5.063	4.981	4.862	4.721	4.583	4.517
EA3301	6	Stressed creep	4.063	3.986	3.873	3.739	3.610	3.547
DW3701	6	Stressed creep	3.063	2.991	2.885	2.759	2.637	2.578
1D	6	Flux Monitor	2.438	2.371	2.274	2.158	2.046	1.992
BP3303	6	Stressed creep	1.813	1.747	1.651	1.537	1.426	1.372
AW3812	6	Piggyback	-1.312	-1.336	-1.370	-1.411	-1.451	-1.470
EW4603	6	Piggyback	-1.562	-1.585	-1.618	-1.658	-1.697	-1.716
TW3823	6	Piggyback	-1.812	-1.834	-1.867	-1.906	-1.944	-1.962
325-11	6	Piggyback	-2.062	-2.084	-2.117	-2.155	-2.193	-2.211
P3-09	6	Piggyback	-2.312	-2.334	-2.366	-2.404	-2.442	-2.459
BP3602	6	Unstressed control	-2.937	-2.958	-2.989	-3.026	-3.062	-3.080
DA3608	6	Piggyback	-3.562	-3.582	-3.612	-3.648	-3.682	-3.699
DW3704	6	Unstressed control	-4.187	-4.206	-4.235	-4.268	-4.301	-4.317
EA3201	6	Unstressed control	-5.187	-5.205	-5.231	-5.261	-5.291	-5.306
AP3103	6	Unstressed control	-6.187	-6.203	-6.227	-6.255	-6.282	-6.296
TW3503	6	Unstressed control	-7.187	-7.202	-7.224	-7.250	-7.276	-7.288
BP3605	6	Unstressed control	-8.187	-8.201	-8.222	-8.246	-8.270	-8.282
DA3607	6	Piggyback	-8.812	-8.825	-8.845	-8.868	-8.891	-8.901
DA3401	6	Unstressed control	-9.437	-9.449	-9.468	-9.489	-9.510	-9.520
EA3204	6	Unstressed control	-10.437	-10.448	-10.464	-10.483	-10.502	-10.511
AW3102	6	Unstressed control	-11.437	-11.447	-11.461	-11.478	-11.494	-11.502
TW3506	6	Unstressed control	-12.437	-12.446	-12.458	-12.473	-12.488	-12.495
BL3203	6	Unstressed control	-13.437	-13.445	-13.456	-13.470	-13.483	-13.490
DW3903	6	Unstressed control	-14.437	-14.444	-14.454	-14.465	-14.477	-14.482
AH	6	Flux Monitor	-15.062	-15.068	-15.077	-15.087	-15.097	-15.102
EW3501	6	Unstressed control	-15.687	-15.692	-15.700	-15.710	-15.719	-15.724
AL3103	6	Unstressed control	-16.687	-16.692	-16.698	-16.706	-16.714	-16.717
BP3703	6	Unstressed control	-17.687	-17.691	-17.696	-17.703	-17.709	-17.712
DA3104	6	Unstressed control	-18.687	-18.690	-18.695	-18.700	-18.705	-18.708
TW3509	6	Unstressed control	-19.687	-19.690	-19.693	-19.698	-19.702	-19.704
DA3606	6	Piggyback	-20.312	-20.314	-20.318	-20.322	-20.326	-20.328
EW3504	6	Unstressed control	-20.937	-20.939	-20.942	-20.945	-20.949	-20.951
BL3603	6	Piggyback	-21.562	-21.564	-21.566	-21.569	-21.572	-21.574
AL3803	6	Piggyback	-21.812	-21.814	-21.816	-21.819	-21.821	-21.823
EW4511	6	Piggyback	-22.062	-22.063	-22.065	-22.067	-22.069	-22.070
AW3903	6	Piggyback	-22.312	-22.313	-22.314	-22.315	-22.316	-22.317
DW4601	6	Piggyback	-22.562	-22.562	-22.563	-22.564	-22.565	-22.565
DA3512	6	Piggyback	-22.812	-22.812	-22.813	-22.813	-22.813	-22.814
TW3829	6	Piggyback	-23.062	-23.062	-23.062	-23.062	-23.062	-23.062

Title: AGC-3 Specimen Position Calculations by Stack

ECAR No.: 4430 Rev. No.: 0 Project No.: 29412 Date: 06/11/2019

Specimen ID	Stack	Specimen Type	Initial Specimen CoM (in)	152B Mid-Cycle CoM	154B Mid-Cycle CoM	155A Mid-Cycle CoM	155B Mid-Cycle CoM	End of Test CoM
BP3401	7	Piggyback	18.688	18.636	18.559	18.468	18.380	18.337
AP3501	7	Piggyback	18.438	18.386	18.310	18.219	18.131	18.089
EA3504	7	Piggyback	18.188	18.136	18.061	17.971	17.884	17.842
TW3801	7	Piggyback	17.938	17.887	17.812	17.723	17.636	17.594
DA3501	7	Piggyback	17.688	17.637	17.562	17.473	17.387	17.346
CAN101	7	HOPG	17.438	17.387	17.313	17.224	17.139	17.097
CAN129	7	MLRF-1	17.063	17.012	16.939	16.851	16.766	16.724
324-01	7	Piggyback	16.688	16.638	16.564	16.477	16.392	16.352
328-01	7	Piggyback	16.438	16.388	16.315	16.228	16.144	16.103
BW4002	7	Piggyback	16.188	16.138	16.066	15.980	15.896	15.856
AW3801	7	Piggyback	15.938	15.889	15.817	15.731	15.649	15.608
EW4501	7	Piggyback	15.688	15.639	15.568	15.483	15.401	15.362
TW3802	7	Piggyback	15.438	15.390	15.319	15.235	15.153	15.114
DW4502	7	Piggyback	15.188	15.140	15.070	14.986	14.905	14.866
CAN102	7	HOPG	14.938	14.890	14.820	14.737	14.657	14.618
A	7	Piggyback	14.688	14.640	14.570	14.487	14.407	14.368
S1	7	Piggyback	14.438	14.390	14.321	14.238	14.158	14.119
325-01	7	Piggyback	14.188	14.141	14.071	13.989	13.909	13.871
200-01	7	Piggyback	13.938	13.891	13.822	13.740	13.660	13.621
BP3502	7	Piggyback	13.688	13.641	13.572	13.491	13.412	13.373
AP3502	7	Piggyback	13.438	13.391	13.323	13.242	13.163	13.125
EA3505	7	Piggyback	13.188	13.142	13.074	12.994	12.916	12.878
TW3803	7	Piggyback	12.938	12.892	12.825	12.745	12.668	12.630
DA3502	7	Piggyback	12.688	12.642	12.575	12.496	12.419	12.382
CAN103	7	HOPG	12.438	12.392	12.326	12.247	12.170	12.133
CAN121	7	MLRF-1	12.063	12.018	11.952	11.873	11.797	11.760
324-02	7	Piggyback	11.688	11.643	11.578	11.500	11.424	11.387
328-02	7	Piggyback	11.438	11.393	11.328	11.250	11.175	11.139
BW4003	7	Piggyback	11.188	11.144	11.079	11.002	10.927	10.891
AW3802	7	Piggyback	10.938	10.894	10.830	10.753	10.679	10.643
EW4502	7	Piggyback	10.688	10.645	10.581	10.506	10.432	10.397
TW3804	7	Piggyback	10.438	10.395	10.332	10.257	10.185	10.150
DW4503	7	Piggyback	10.188	10.145	10.083	10.009	9.937	9.903
CAN104	7	HOPG	9.938	9.896	9.834	9.761	9.689	9.655
B	7	Piggyback	9.688	9.646	9.584	9.510	9.439	9.405
S2	7	Piggyback	9.438	9.396	9.334	9.260	9.189	9.155
325-02	7	Piggyback	9.188	9.146	9.085	9.012	8.941	8.907
200-02	7	Piggyback	8.938	8.896	8.835	8.763	8.692	8.658
BP3403	7	Piggyback	8.688	8.647	8.586	8.514	8.444	8.411
AP3503	7	Piggyback	8.438	8.397	8.337	8.266	8.197	8.164
EA3506	7	Piggyback	8.188	8.148	8.089	8.018	7.950	7.917
TW3805	7	Piggyback	7.938	7.898	7.840	7.770	7.703	7.670
DA3503	7	Piggyback	7.688	7.648	7.591	7.522	7.455	7.423
CAN105	7	HOPG	7.438	7.399	7.341	7.273	7.207	7.175
CAN122	7	MLRF-1	7.063	7.024	6.967	6.900	6.834	6.803
324-03	7	Piggyback	6.688	6.649	6.593	6.526	6.461	6.429
328-03	7	Piggyback	6.438	6.400	6.343	6.277	6.212	6.181
BW4004	7	Piggyback	6.188	6.150	6.094	6.028	5.964	5.933
AW3803	7	Piggyback	5.938	5.900	5.845	5.780	5.716	5.685
EW4503	7	Piggyback	5.688	5.651	5.597	5.532	5.470	5.440
TW3806	7	Piggyback	5.438	5.401	5.348	5.285	5.223	5.193
DW4504	7	Piggyback	5.188	5.152	5.099	5.037	4.976	4.946
CAN106	7	HOPG	4.938	4.902	4.850	4.788	4.728	4.699
C	7	Piggyback	4.688	4.652	4.600	4.538	4.478	4.449
S3	7	Piggyback	4.438	4.402	4.351	4.289	4.229	4.200
325-03	7	Piggyback	4.188	4.153	4.101	4.040	3.981	3.952

Title: AGC-3 Specimen Position Calculations by Stack

ECAR No.: 4430 Rev. No.: 0 Project No.: 29412 Date: 06/11/2019

Specimen ID	Stack	Specimen Type	Initial Specimen CoM (in)	152B Mid-Cycle CoM	154B Mid-Cycle CoM	155A Mid-Cycle CoM	155B Mid-Cycle CoM	End of Test CoM
200-03	7	Piggyback	3.938	3.903	3.852	3.792	3.733	3.704
BP3404	7	Piggyback	3.688	3.653	3.603	3.543	3.484	3.456
AP3504	7	Piggyback	3.438	3.404	3.354	3.295	3.237	3.209
EA3507	7	Piggyback	3.188	3.154	3.105	3.047	2.990	2.963
TW3807	7	Piggyback	2.938	2.905	2.857	2.799	2.744	2.717
DA3504	7	Piggyback	2.688	2.655	2.608	2.551	2.496	2.469
CAN107	7	HOPG	2.438	2.406	2.359	2.302	2.248	2.222
CAN123	7	MLRF-1	2.063	2.031	1.984	1.929	1.875	1.849
324-04	7	Piggyback	1.688	1.656	1.610	1.555	1.502	1.476
328-04	7	Piggyback	1.438	1.407	1.361	1.306	1.253	1.228
BW4005	7	Piggyback	1.188	1.157	1.111	1.057	1.005	0.980
AW3804	7	Piggyback	0.938	0.907	0.862	0.809	0.757	0.732
EW4504	7	Piggyback	0.688	0.658	0.614	0.562	0.511	0.487
TW3808	7	Piggyback	0.438	0.409	0.366	0.314	0.265	0.241
DW4505	7	Piggyback	0.188	0.159	0.117	0.066	0.018	-0.006
CAN108	7	HOPG	-0.062	-0.091	-0.132	-0.182	-0.230	-0.253
D	7	Piggyback	-0.312	-0.340	-0.382	-0.431	-0.479	-0.503
S4	7	Piggyback	-0.562	-0.590	-0.632	-0.681	-0.728	-0.751
325-04	7	Piggyback	-0.812	-0.840	-0.881	-0.929	-0.976	-0.999
200-04	7	Piggyback	-1.062	-1.090	-1.130	-1.178	-1.225	-1.247
BP3405	7	Piggyback	-1.312	-1.339	-1.379	-1.426	-1.472	-1.494
AP3505	7	Piggyback	-1.562	-1.589	-1.628	-1.674	-1.719	-1.740
EA3508	7	Piggyback	-1.812	-1.838	-1.876	-1.921	-1.965	-1.986
TW3809	7	Piggyback	-2.062	-2.087	-2.125	-2.169	-2.212	-2.233
DA3505	7	Piggyback	-2.312	-2.337	-2.374	-2.417	-2.459	-2.480
CAN109	7	HOPG	-2.562	-2.587	-2.623	-2.666	-2.707	-2.728
CAN124	7	MLRF-1	-2.937	-2.961	-2.997	-3.039	-3.080	-3.100
324-05	7	Piggyback	-3.312	-3.336	-3.371	-3.413	-3.454	-3.473
328-05	7	Piggyback	-3.562	-3.586	-3.621	-3.662	-3.703	-3.722
BW4006	7	Piggyback	-3.812	-3.836	-3.870	-3.911	-3.951	-3.970
AW3805	7	Piggyback	-4.062	-4.085	-4.119	-4.160	-4.199	-4.218
EW4505	7	Piggyback	-4.312	-4.335	-4.368	-4.407	-4.445	-4.464
TW3810	7	Piggyback	-4.562	-4.584	-4.616	-4.655	-4.692	-4.710
DW4506	7	Piggyback	-4.812	-4.834	-4.865	-4.903	-4.939	-4.957
CAN110	7	HOPG	-5.062	-5.083	-5.114	-5.151	-5.187	-5.204
E	7	Piggyback	-5.312	-5.333	-5.364	-5.401	-5.436	-5.454
S5	7	Piggyback	-5.562	-5.583	-5.614	-5.650	-5.686	-5.703
325-05	7	Piggyback	-5.812	-5.833	-5.863	-5.899	-5.934	-5.951
200-05	7	Piggyback	-6.062	-6.082	-6.112	-6.148	-6.183	-6.199
BP3406	7	Piggyback	-6.312	-6.332	-6.362	-6.397	-6.431	-6.447
AP3506	7	Piggyback	-6.562	-6.582	-6.610	-6.645	-6.678	-6.694
EA3509	7	Piggyback	-6.812	-6.831	-6.859	-6.892	-6.925	-6.940
TW3811	7	Piggyback	-7.062	-7.081	-7.108	-7.141	-7.172	-7.187
DA3506	7	Piggyback	-7.312	-7.330	-7.357	-7.389	-7.420	-7.435
CAN111	7	HOPG	-7.562	-7.580	-7.606	-7.638	-7.668	-7.682
CAN125	7	MLRF-1	-7.937	-7.955	-7.980	-8.011	-8.041	-8.055
324-06	7	Piggyback	-8.312	-8.329	-8.355	-8.385	-8.414	-8.429
328-06	7	Piggyback	-8.562	-8.579	-8.605	-8.635	-8.664	-8.678
BW4007	7	Piggyback	-8.812	-8.829	-8.854	-8.884	-8.912	-8.926
AW3806	7	Piggyback	-9.062	-9.079	-9.103	-9.132	-9.160	-9.173
EW4506	7	Piggyback	-9.312	-9.328	-9.351	-9.379	-9.406	-9.419
TW3812	7	Piggyback	-9.562	-9.577	-9.600	-9.627	-9.653	-9.666
DW4507	7	Piggyback	-9.812	-9.827	-9.849	-9.875	-9.900	-9.913
CAN112	7	HOPG	-10.062	-10.077	-10.098	-10.124	-10.148	-10.160
F	7	Piggyback	-10.312	-10.327	-10.348	-10.373	-10.398	-10.410
S6	7	Piggyback	-10.562	-10.576	-10.598	-10.623	-10.647	-10.659

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Specimen ID	Stack	Specimen Type	Initial Specimen CoM (in)	152B Mid-Cycle CoM	154B Mid-Cycle CoM	155A Mid-Cycle CoM	155B Mid-Cycle CoM	End of Test CoM
325-06	7	Piggyback	-10.812	-10.826	-10.847	-10.872	-10.895	-10.907
200-06	7	Piggyback	-11.062	-11.076	-11.096	-11.120	-11.144	-11.155
BP3407	7	Piggyback	-11.312	-11.326	-11.345	-11.369	-11.392	-11.403
AP3507	7	Piggyback	-11.562	-11.575	-11.594	-11.617	-11.639	-11.650
EA3510	7	Piggyback	-11.812	-11.825	-11.843	-11.865	-11.886	-11.897
TW3813	7	Piggyback	-12.062	-12.074	-12.092	-12.113	-12.134	-12.144
DA3507	7	Piggyback	-12.312	-12.324	-12.341	-12.362	-12.382	-12.391
CAN113	7	HOPG	-12.562	-12.574	-12.590	-12.610	-12.630	-12.639
CAN126	7	MLRF-1	-12.937	-12.948	-12.964	-12.984	-13.003	-13.012
324-07	7	Piggyback	-13.312	-13.323	-13.339	-13.358	-13.376	-13.385
328-07	7	Piggyback	-13.562	-13.573	-13.588	-13.607	-13.625	-13.633
BW4101	7	Piggyback	-13.812	-13.822	-13.838	-13.856	-13.873	-13.882
AW3808	7	Piggyback	-14.062	-14.072	-14.087	-14.104	-14.121	-14.129
EW4507	7	Piggyback	-14.312	-14.321	-14.335	-14.352	-14.368	-14.375
TW3814	7	Piggyback	-14.562	-14.571	-14.584	-14.600	-14.615	-14.622
DW4508	7	Piggyback	-14.812	-14.821	-14.833	-14.848	-14.863	-14.870
CAN114	7	HOPG	-15.062	-15.070	-15.082	-15.097	-15.111	-15.118
G	7	Piggyback	-15.312	-15.320	-15.332	-15.347	-15.361	-15.367
S7	7	Piggyback	-15.562	-15.570	-15.582	-15.596	-15.610	-15.616
325-07	7	Piggyback	-15.812	-15.820	-15.831	-15.845	-15.858	-15.864
200-07	7	Piggyback	-16.062	-16.070	-16.081	-16.094	-16.106	-16.112
BP3408	7	Piggyback	-16.312	-16.319	-16.330	-16.343	-16.355	-16.361
AP3508	7	Piggyback	-16.562	-16.569	-16.579	-16.591	-16.603	-16.609
EA3511	7	Piggyback	-16.812	-16.818	-16.828	-16.839	-16.850	-16.856
TW3815	7	Piggyback	-17.062	-17.068	-17.077	-17.088	-17.098	-17.103
DA3508	7	Piggyback	-17.312	-17.318	-17.326	-17.336	-17.345	-17.350
CAN115	7	HOPG	-17.562	-17.567	-17.575	-17.584	-17.593	-17.597
CAN127	7	MLRF-1	-17.937	-17.942	-17.949	-17.958	-17.966	-17.970
324-08	7	Piggyback	-18.312	-18.317	-18.323	-18.331	-18.339	-18.343
328-08	7	Piggyback	-18.562	-18.566	-18.573	-18.581	-18.588	-18.592
BW4102	7	Piggyback	-18.812	-18.816	-18.822	-18.830	-18.837	-18.841
AW3809	7	Piggyback	-19.062	-19.066	-19.072	-19.079	-19.086	-19.089
EW4508	7	Piggyback	-19.312	-19.316	-19.321	-19.327	-19.333	-19.336
TW3816	7	Piggyback	-19.562	-19.565	-19.570	-19.575	-19.581	-19.583
DW4509	7	Piggyback	-19.812	-19.815	-19.819	-19.824	-19.829	-19.831
CAN116	7	HOPG	-20.062	-20.065	-20.068	-20.073	-20.077	-20.080
H	7	Piggyback	-20.312	-20.315	-20.318	-20.323	-20.327	-20.329
S8	7	Piggyback	-20.562	-20.565	-20.568	-20.573	-20.577	-20.579
325-08	7	Piggyback	-20.812	-20.814	-20.818	-20.822	-20.827	-20.829
200-08	7	Piggyback	-21.062	-21.064	-21.068	-21.072	-21.076	-21.077
BP3409	7	Piggyback	-21.312	-21.314	-21.317	-21.321	-21.325	-21.326
AP3509	7	Piggyback	-21.562	-21.564	-21.567	-21.570	-21.573	-21.575
EA3512	7	Piggyback	-21.812	-21.814	-21.816	-21.819	-21.821	-21.823
TW3817	7	Piggyback	-22.062	-22.063	-22.065	-22.067	-22.070	-22.071
DA3509	7	Piggyback	-22.312	-22.313	-22.315	-22.317	-22.319	-22.319
CAN117	7	HOPG	-22.562	-22.563	-22.564	-22.566	-22.567	-22.568
CAN128	7	MLRF-1	-22.937	-22.938	-22.938	-22.939	-22.940	-22.941
324-09	7	Piggyback	-23.312	-23.312	-23.313	-23.313	-23.314	-23.314
328-09	7	Piggyback	-23.562	-23.562	-23.562	-23.562	-23.562	-23.562