



ECAR-1944 AGC-1 AS RUN THERMAL RESULTS

August 2021

Changing the World's Energy Future

Grant L Hawkes



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ECAR-1944 AGC-1 AS RUN THERMAL RESULTS

Grant L Hawkes

August 2021

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Engineering Calculations and Analysis

ECAR Title: AGC-1 As Run Thermal ResultsECAR No.: 1944

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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.

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2. QL Determination No.	QLD REC-000169	
3. Engineering Job (EJ) No.	N/A	
4. SSC ID	N/A	
5. Building	670	
6. Site Area	ATR Complex	
7. Objective/Purpose: Purpose of this ECAR is to provide documentation of as-run analysis results for each specimen temperature in the AGC-1 test train at specific time points during the irradiation.		
8. If revision, please state the reason and list sections and/or pages being affected: 		
9. Conclusions/Recommendations: The temperature history for each specimen is provided at specific time points during the irradiation using as-run conditions for outer shim position, reactor source power, specific control gas mixtures and material thermal conductivities as calculated based on fluence at the specific time points. Volume average temperatures for each specimen were calculated based on the ABAQUS analysis results, and the volume of each cell in the specimen.		

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PROJECT ROLES AND RESPONSIBILITIES

Project Role	Name (Typed)	Organization	Pages covered (if applicable)
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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 expanded or reduced.*

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SCOPE AND BRIEF DESCRIPTION

Scope of the analysis was to provide the volume average temperature for each specimen in the AGC-1 test train at specific points during the irradiation. The predictions were to be based on as-run conditions at the specific time point. These as-run conditions were outer shim control cylinder position, reactor source power, control gas mixture, and graphite thermal conductivity based on the fast fluence at the specific time point.

DESIGN OR TECHNICAL PARAMETER INPUT AND SOURCES

The input data were obtained from the ASUDAS report for the reactor cycles, physics calculations to provide the material heat rates and fast fluence.

RESULTS OF LITERATURE SEARCHES AND OTHER BACKGROUND DATA

The physics and thermal models were the same as used for the AGC-1 final design analyses as reported in ECAR-215 and ECAR-364.

ASSUMPTIONS

1. The test was irradiated in the ATR South flux trap.
2. The graphite thermal conductivity was based on POCO-AXM 5Q1 un-irradiated data with

DPA= Fast Fluence (n/m^2) X $8.23E-26$ (ECAR-968)

$k(irr) = ((0.25 - 0.00017 * T(irr))^A * \log(DPA) + 0.000683 * T(irr)) * k(non)$ (ECAR-968)

where $k(irr)$ is the irradiated thermal conductivity, $T(irr)$ is the irradiation temperature in °C, $A = -1.0$, and $k(non)$ is the non-irradiated thermal conductivity.

3. The control annulus between the graphite holder and the thermal shield was assumed to increase due to shrinkage of the graphite holder based on H-451 data which provided the relationship

Shrinkage (%) = $0.15 * DPA$

as shown in Appendix C. Also shown in Appendix C is dimensional change data for GraphNOL N3M graphite.

COMPUTER CODE VALIDATION

Refer to ECAR-215 and ECAR-364

ABAQUS Version 6.9-2 was used to do the mesh creation, boundary conditions, solving, and post processing. The computer named lcestorm was used to run ABAQUS. Appendix A is the validation report of ABAQUS Version 6.9-2 run on lcestorm. The report is comprised of 10 thermal models validating different aspects of ABAQUS' heat transfer abilities. The maximum difference between ABAQUS calculated values and exact theoretical values is just under 2.0%. Many of the test problems have 0% error.

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DISCUSSION/ANALYSIS

The following list shows the AGC detailed MCNP physics analysis file names, cycle, date, EFPD, and fluence. The agc files are located on the HPC machines in /projects/AGC/agc-1_asrun/heating for the first four cycles, and /projects/AGC/agc-1_asrun/rotated_heating for the last three cycles. The file names and the associated physics data were as tabulated:

File Name	Cycle	Shim and Power		Cumulative		South Power	Peak Fluence
		Date	EFPD	EFPD	(MW)	Center	(n/cm ²)
agc5a1.AGC	145A1	9/20/2009 16:00	15	15.0	24.5	4.38E+20	
agc5a2.Agc	145A2	10/11/2009 17:00	20	35.0	24.0	9.79E+20	
agc5a3.Agc	145A3	11/6/2009 4:59	19.6	54.6	24.4	1.50E+21	
agc5a4.Agc	145A4	11/6/2009 4:59	0.0001	54.6	24.4	1.50E+21	
agc5b1.Agc	145B1	12/19/2009 11:59	22	76.6	24.6	2.13E+21	
agc5b2.Agc	145B2	1/10/2010 11:59	22	98.6	24.4	2.71E+21	
agc5b3.Agc	145B3	1/23/2010 4:59	13.3	111.9	24.7	3.07E+21	
agc5b4.Agc	145B4	1/23/2010 4:59	0.0001	111.9	24.7	3.07E+21	
agc6a1.Agc	146A1	2/24/2010 4:59	16	127.9	25.4	3.53E+21	
agc6a2.Agc	146A2	3/12/2010	16	143.9	25.3	3.98E+21	
agc6a3.Agc	146A3	4/3/2010 10:00	18.5	162.4	25.0	4.49E+21	
agc6b1.Agc	146B1	2/24/2010 4:59	18	180.4	25.1	4.98E+21	
agc6b2.Agc	146B2	5/19/2010 10:59	10	190.4	25.2	5.25E+21	
agc6b3.Agc	146B3	5/30/2010 8:00	11.2	201.6	25.1	5.56E+21	
agc6b4.Agc	146B4	5/30/2010 8:00	0.0001	201.6	25.1	5.56E+21	
agc7a1.Agc	147A1	7/8/2010 4:59	15	216.6	22.7	5.96E+21	
agc7a2.Agc	147A2	7/26/2010 5:00	18	234.6	22.8	6.42E+21	
agc7a3.Agc	147A3	8/13/2010 9:59	18.5	253.1	22.9	6.84E+21	
agc7a4.Agc	147A4	8/14/2010 10:00	0.0001	253.1	22.7	6.86E+21	
agc8a1.Agc	148A1	9/29/2010 12:00	28	281.1	22.8	7.60E+21	
agc8a2.Agc	148A2	10/9/2010 12:00	10	291.1	23.0	7.87E+21	
agc8a3.Agc	148A3	10/22/2010 11:59	8.5	299.6	23.6	8.10E+21	
agc8a4.Agc*	148A4	10/23/2010 9:59	0.0001	299.6	23.5	8.13E+21	
agc8b1.Agc	148B1	12/6/2010 11:59	18	317.6	23.2	8.60E+21	
agc8b2.Agc	148B2	12/24/2010 11:59	18	335.6	23.5	9.11E+21	
agc8b3.Agc*	148B3	1/8/2011 9:59	15.5	351.1	23.1	9.52E+21	
agc8b4.Agc	148B4	1/8/2011 9:59	0.0001	351.1	23.1	9.52E+21	

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The gas mixtures used for calculating the control gas thermal conductivity were as follow: Data comes from the NDMAS database.

Cycle	Standard_Date_Time	Chan7 He (sccm)	Chan7 Ar (sccm)	Chan8 He (sccm)	Chan8 Ar (sccm)
145A1	9/20/2009 16:00	48.33556	1.664913	49.79804	0.1980847
145A2	10/11/2009 17:00	48.03655	1.954612	49.83721	0.1761322
145A3/A4	11/6/2009 5:00	47.93652	2.062193	49.88387	0.09035707
145B1	12/19/2009 12:00	47.41818	2.568057	49.90313	0.1007468
145B2	1/10/2010 12:00	47.21896	2.783263	49.91912	0.07802981
145B3/B4	1/23/2010 5:00	12.21018	2.79786	14.87714	0.1296331
146A1	2/24/2010 5:00	39.19791	10.50783	37.40329	12.71803
146A2	3/12/2010 0:00	49.25605	0.7097239	49.50785	0.4440782
146A3	4/3/2010 10:00	14.10978	0.7519571	14.57675	0.4623907
146B1	5/9/2010 5:00	48.23028	1.771829	49.62406	0.3667358
146B2	5/19/2010 11:00	48.20163	1.797135	49.58725	0.413728
146B3/B4	5/30/2010 8:00	14.06997	1.931625	15.53934	0.4533383
147A1	7/8/2010 5:00	48.9886	1.017647	49.60371	0.4086777
147A2	7/26/2010 5:00	48.60871	1.392734	49.63097	0.3700342
147A3	8/13/2010 10:00	48.05027	1.945068	49.66344	0.3412129
147A4	8/14/2010 10:00	13.02801	1.962585	14.67684	0.3213167
148A1	9/29/2010 12:00	42.93354	7.065055	49.82602	0.1784358
148A2	10/9/2010 12:00	42.68771	7.319093	49.89396	0.1399958
148A3	10/22/2010 12:00	35.88147	14.1116	49.88474	0.1333486
148A4*	10/19/2010 10:00	38.705	11.3055	49.87593	0.1511008
148B1	12/6/2010 12:00	42.80106	7.208002	49.89871	0.08894221
148B2	12/24/2010 12:00	42.52065	7.475739	49.87922	0.09771028
148B3/B4*	1/7/2011 10:00	41.70766	8.29025	49.89807	0.1009373

*The gas mixtures for runs 148A4 and 148B3/B4 were shifted ahead by three days and one day respectively. This was done to have a more representative gas flow as the actual ones were very different and caused increased temperatures of about 80°C. The heat rates were taken from the original times. A more representative temperature near the end of the cycle has been calculated in this fashion.

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Tables 1 through 9 show the volume average temperature results for various times during the AGC-1 irradiation in ATR. Figures 1 through 8 show axial temperature profiles of the specimens. Figures 9 through 12 show the actual temperatures measured with TCs and are compared to the calculated temperatures. Four points in time were compared. Both measured and calculated temperatures tend to trend upwards through the experiment. This occurs since the graphite shrinks and causes the control gas gap to increase. Also the graphite conductivity decreases with an increase of fluence. Figures 12 through 14 show the delta temperature between the measured and calculated for the TC locations. Most of the delta temperatures go negative with time, meaning that the predictions are higher than the measured values. TC 2 seems to be very different than the other TCs as the delta goes to almost -125°C. The majority of the deltas end up at the final time being between -25°C and -50°C. The model has been configured to capture the phenomena known to be occurring in the experiment.

The graphite shrinks with time during the irradiation, causing the control gas gap to widen. This was implemented in ABAQUS with the FIELD VARIABLE option. Field variable # 2 in the ABAQUS model is for fluence. The model was broken into several axial heights with nodesets. Each was given fluence for each of the 23 runs that were made. These fluence values came from the detailed physics analyses. Each axial height had a different fluence. The graphite conductivity and the control gas gap depended on these fluence values. As the graphite shrank, the control gap would get bigger. This was implemented by having the thermal conductivity decrease in the control gas gap to account for the larger gap. The order that these fluence values are input into the ABAQUS were important, as ABAQUS uses the last value if there are nodes that have been specified more than once.

The thermal conductivity of POCO-AXM 5Q1 was used in these as-run calculations. NBG-25 graphite was actually used in the experiment. The conductivities are very close and will not affect the results. The following two tables show the unirradiated thermal conductivities of each of these graphites. These are the original conductivities used in the original AGC-1 scoping calculations, but no reference is made from ECAR-364. These values were obtained from the ABAQUS input files.

NBG-25		POCO-AXM 5Q1	
Temp (°F)	k (Btu/s-in-°F)	Temp (°F)	k (Btu/s-in-°F)
220	1.28E-03	220	1.28E-03
400	1.26E-03	400	1.26E-03
572	1.44E-03	580	1.25E-03
752	1.18E-03	940	1.12E-03
1112	1.00E-03	1310	9.62E-04
1472	8.96E-04	1660	8.68E-04
1832	8.03E-04	2040	7.58E-04
		2530	6.88E-04
		3190	6.15E-04

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Table 1. S-1 specimen temperatures (°C) with ATR cycle averages.

S-1										
ATR	Elevation									AGC-1
Stack #	Above	145A	145B	146A	146B	147A	148A	148B	Experiment	
Naming	Mid-Plane	Average	Average	Average	Average	Average	Average	Average	Average	
S1-TF-15	19.25	534.17	578.12	623.20	595.84	571.82	602.46	584.44	583.06	
S1-TF-14	18.00	545.01	587.64	634.35	609.94	583.54	616.57	600.74	595.46	
S1-TF-13	16.75	546.93	586.58	634.31	613.70	586.10	621.33	608.17	598.10	
S1-TF-12	15.50	556.95	598.02	648.00	630.89	602.51	639.97	629.81	613.47	
S1-TF-11	14.25	566.92	609.51	661.74	648.96	620.00	659.78	652.82	629.46	
S1-TF-10	13.00	574.59	617.90	671.67	663.05	632.81	675.80	671.45	641.76	
S1-TF-09	11.75	585.37	630.39	685.97	681.85	649.61	696.34	693.71	658.09	
S1-TF-08	10.50	589.95	635.15	692.68	692.99	658.95	708.75	707.77	666.87	
S1-TF-07	9.25	587.36	631.51	690.49	695.49	660.57	713.51	714.47	667.70	
S1-TF-06	8.00	592.18	636.67	697.14	705.06	668.78	724.43	727.34	675.86	
S1-TF-05	6.75	600.34	645.20	707.28	716.56	679.23	737.08	741.97	686.62	
S1-TF-04	5.50	608.48	653.84	717.48	727.79	689.75	749.60	756.18	697.31	
S1-TF-03	4.25	614.74	660.22	724.70	735.93	697.00	758.41	766.55	705.03	
S1-TF-02	3.00	617.50	662.86	727.91	740.01	700.31	762.71	771.84	708.64	
S1-TF-01	1.75	614.82	660.05	725.11	737.28	697.91	760.52	770.04	706.15	
S1-BP-01	-1.63	585.65	629.09	692.69	708.09	670.74	731.13	742.13	676.66	
S1-BP-02	-2.13	586.40	630.37	694.09	709.54	672.18	732.47	743.33	677.91	
S1-BP-03	-2.63	586.72	630.97	694.51	709.96	672.82	732.78	743.71	678.36	
S1-BP-04	-3.13	586.55	630.85	694.37	709.76	672.78	732.32	743.36	678.15	
S1-BP-05	-3.63	585.92	630.48	693.72	709.07	672.37	731.41	742.45	677.51	
S1-BP-06	-4.13	585.16	629.96	692.68	707.93	671.82	730.39	741.21	676.62	
S1-BP-07	-4.63	584.37	629.45	691.74	706.85	671.18	729.30	739.81	675.72	
S1-BF-01	-5.50	583.47	628.93	690.70	705.35	670.10	727.49	737.28	674.40	
S1-BF-02	-6.75	582.18	627.68	688.94	702.36	667.69	723.74	732.00	671.78	
S1-BF-03	-8.00	584.19	630.51	691.02	702.31	667.11	722.32	728.30	672.03	
S1-BF-04	-9.25	579.37	625.21	684.18	693.58	658.58	712.00	716.11	664.05	
S1-BF-05	-10.50	568.16	613.42	671.07	678.72	645.12	695.75	698.44	650.11	
S1-BF-06	-11.75	553.21	597.86	653.44	659.07	627.84	674.61	676.37	631.94	
S1-BF-07	-13.00	536.68	580.30	633.01	636.42	607.08	649.36	650.18	610.79	
S1-BF-08	-14.25	522.38	564.56	614.76	615.54	588.08	626.68	625.85	591.67	
S1-BF-09	-15.50	515.64	557.06	605.54	601.65	575.60	611.20	607.76	579.98	
S1-BF-10	-16.75	517.77	562.23	609.57	600.26	574.65	608.92	601.86	580.28	
S1-BF-11	-18.00	504.78	547.74	593.15	580.34	555.01	587.57	578.00	562.09	
S1-BF-12	-19.25	481.72	520.64	564.27	549.78	525.39	554.54	543.98	532.80	
S1-BF-13	-20.50	455.89	491.93	534.96	520.53	497.37	523.22	511.26	503.55	
S1-BF-14	-21.75	422.59	455.53	498.51	485.23	464.67	487.61	475.08	468.42	
S1-BP-08	-22.63	392.64	423.47	465.06	454.17	435.76	456.77	445.19	437.53	
S1-BP-09	-23.13	376.53	407.85	452.52	444.81	426.90	447.01	436.90	425.82	
S1-BP-10	-23.63	356.21	387.20	434.16	429.77	413.41	432.77	424.69	409.30	

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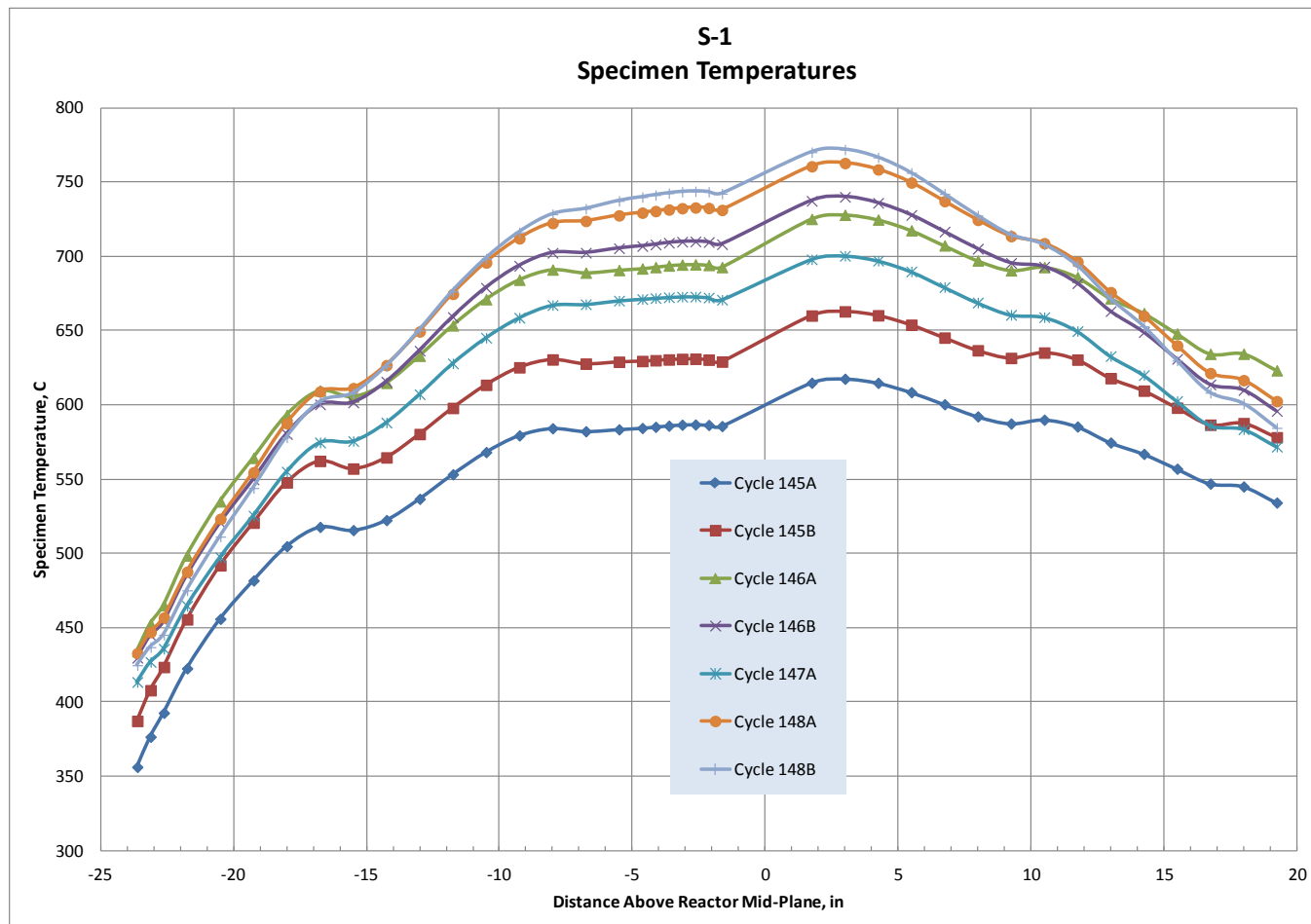


Figure 1. S-1 specimen axial temperature (°C) profile varying by ATR cycle.

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Table 2. S-2 specimen temperatures (°C) with ATR cycle averages.

S-2									
ATR Stack # Naming	Elevation Above Mid-Plane	145A Average	145B Average	146A Average	146B Average	147A Average	148A Average	148B Average	AGC-1 Experiment Average
S2-TF-15	19.25	535.91	580.33	620.84	593.60	574.37	605.23	587.33	584.26
S2-TF-14	18.00	547.16	590.46	631.56	607.59	586.58	619.77	604.06	596.95
S2-TF-13	16.75	549.45	589.88	631.39	611.09	589.61	624.99	612.01	599.88
S2-TF-12	15.50	559.81	601.68	644.80	627.95	606.43	644.02	633.92	615.43
S2-TF-11	14.25	570.07	613.56	658.32	645.75	624.09	664.04	657.30	631.58
S2-TF-10	13.00	577.94	622.01	668.17	659.80	637.13	680.29	676.06	643.99
S2-TF-09	11.75	588.85	634.45	682.59	678.65	653.84	700.85	698.42	660.36
S2-TF-08	10.50	593.51	639.40	689.15	689.68	663.21	713.46	712.63	669.20
S2-TF-07	9.25	591.10	635.89	686.94	692.59	664.96	718.16	719.52	670.16
S2-TF-06	8.00	596.06	641.04	693.44	701.89	673.40	729.23	732.44	678.35
S2-TF-05	6.75	604.26	649.59	703.42	713.29	683.90	742.13	747.27	689.16
S2-TF-04	5.50	612.53	658.49	713.75	724.60	694.43	754.74	761.60	699.97
S2-TF-03	4.25	618.58	664.68	720.99	732.74	701.66	763.58	771.93	707.62
S2-TF-02	3.00	621.39	667.33	724.43	736.70	704.89	767.70	777.17	711.22
S2-TF-01	1.75	618.82	664.44	721.55	734.09	702.41	765.42	775.26	708.69
S2-BP-01	-1.63	589.30	633.46	689.43	705.17	675.19	736.03	747.17	679.19
S2-BP-02	-2.13	590.21	634.76	690.83	706.69	676.74	737.40	748.44	680.50
S2-BP-03	-2.63	590.43	635.32	691.23	706.92	677.32	737.90	748.80	680.92
S2-BP-04	-3.13	590.25	635.25	691.09	706.57	677.29	737.58	748.49	680.72
S2-BP-05	-3.63	589.76	634.88	690.41	705.88	676.83	736.72	747.52	680.09
S2-BP-06	-4.13	588.96	634.38	689.35	704.83	676.18	735.51	746.22	679.17
S2-BP-07	-4.63	588.24	633.86	688.37	703.68	675.58	734.36	744.93	678.27
S2-BF-01	-5.50	587.38	633.38	687.46	702.22	674.67	732.52	742.36	677.00
S2-BF-02	-6.75	585.96	632.17	685.61	699.31	672.21	728.71	737.19	674.37
S2-BF-03	-8.00	588.01	634.95	687.64	699.07	671.84	727.45	733.53	674.65
S2-BF-04	-9.25	583.32	629.86	680.86	690.20	663.49	717.20	721.50	666.77
S2-BF-05	-10.50	572.20	618.26	667.73	675.41	650.12	700.99	703.82	652.90
S2-BF-06	-11.75	557.02	602.46	650.24	655.89	632.55	679.55	681.46	634.56
S2-BF-07	-13.00	540.25	584.50	629.75	633.11	611.37	653.89	654.97	613.12
S2-BF-08	-14.25	525.76	568.61	611.54	612.36	592.21	631.19	630.52	593.93
S2-BF-09	-15.50	518.75	561.08	602.27	598.40	579.57	615.76	612.28	582.14
S2-BF-10	-16.75	520.67	565.95	606.14	596.97	578.45	613.30	606.15	582.24
S2-BF-11	-18.00	507.51	551.09	589.89	577.12	558.67	591.55	582.09	563.90
S2-BF-12	-19.25	484.13	523.80	561.16	546.71	528.66	558.19	547.64	534.40
S2-BF-13	-20.50	458.05	494.75	532.23	517.69	500.29	526.48	514.56	504.98
S2-BF-14	-21.75	424.49	457.87	495.95	482.79	467.31	490.46	478.09	469.66
S2-BP-08	-22.63	394.40	425.66	462.70	451.86	438.37	459.59	448.12	438.75
S2-BP-09	-23.13	378.47	410.33	450.10	442.29	430.02	450.27	440.34	427.29
S2-BP-10	-23.63	358.17	389.84	431.84	427.24	416.85	436.38	428.46	410.96

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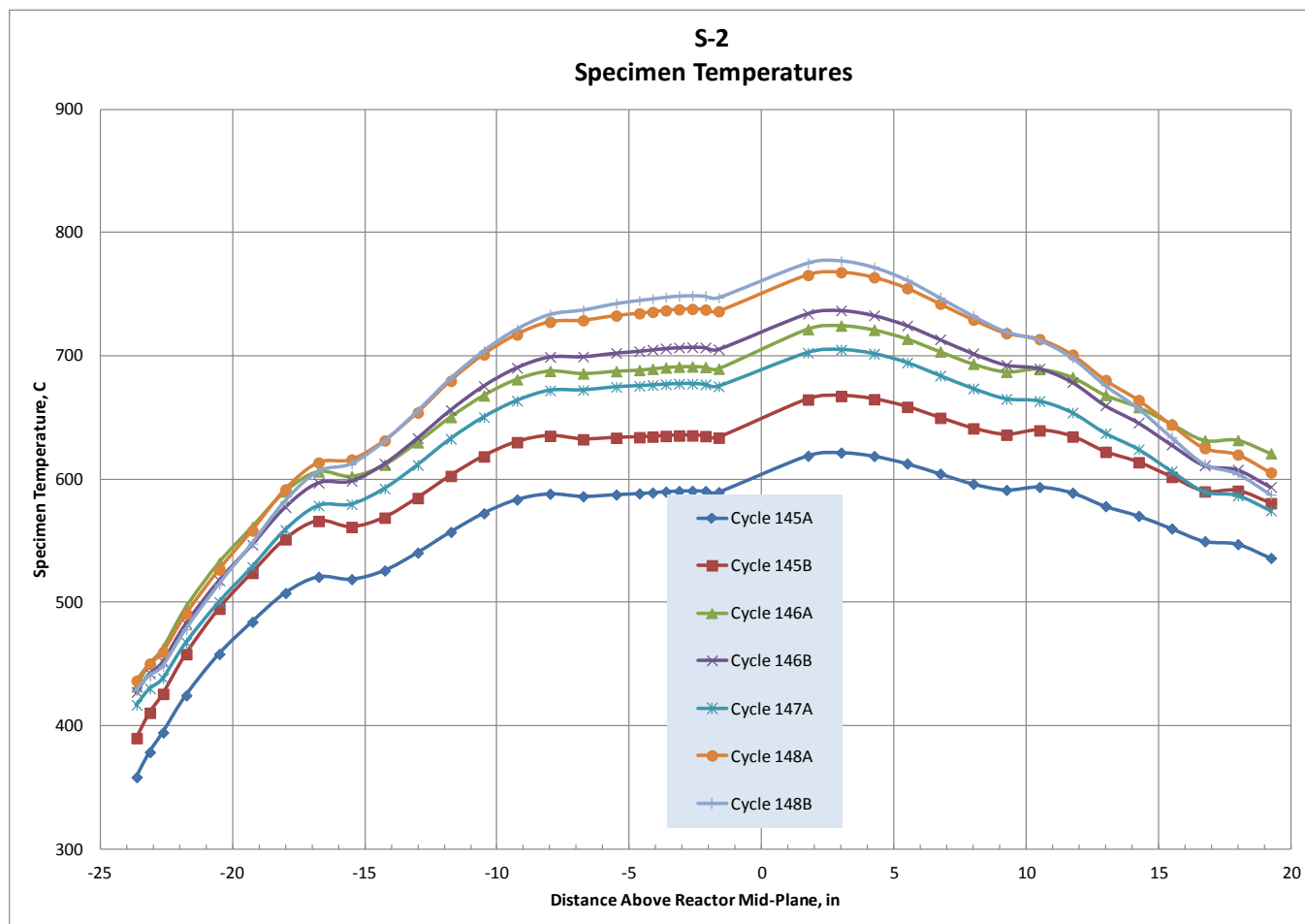


Figure 2. S-2 specimen axial temperature (°C) profile varying by ATR cycle.

Title: AGC-1 As Run Thermal Results

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Date: 09/20/2012

Table 3. S-3 specimen temperatures (°C) with ATR cycle averages.

S-3									
ATR Stack # Naming	Elevation Above Mid-Plane	145A Average	145B Average	146A Average	146B Average	147A Average	148A Average	148B Average	AGC-1 Experiment Average
S3-TF-15	19.25	539.53	584.86	615.88	588.60	579.49	610.15	591.97	586.37
S3-TF-14	18.00	551.42	595.89	625.93	601.62	592.57	625.58	609.52	599.46
S3-TF-13	16.75	554.34	595.92	625.05	604.35	596.31	631.63	618.20	602.73
S3-TF-12	15.50	565.22	608.24	637.83	620.53	613.62	651.15	640.60	618.49
S3-TF-11	14.25	575.95	620.57	650.88	638.00	631.77	671.54	664.44	634.86
S3-TF-10	13.00	584.18	629.23	660.45	651.81	645.04	688.18	683.63	647.45
S3-TF-09	11.75	595.37	641.88	674.77	670.32	661.92	708.96	706.09	663.91
S3-TF-08	10.50	600.17	647.07	681.36	681.04	671.40	721.68	720.49	672.85
S3-TF-07	9.25	597.90	643.75	678.92	683.65	673.37	726.58	727.60	673.88
S3-TF-06	8.00	602.96	648.90	685.24	693.01	681.90	737.68	740.69	682.11
S3-TF-05	6.75	611.31	657.52	695.18	704.44	692.42	750.67	755.52	692.96
S3-TF-04	5.50	619.48	666.21	705.54	715.72	702.87	763.33	769.94	703.73
S3-TF-03	4.25	625.66	672.56	712.98	723.94	710.29	772.22	780.28	711.50
S3-TF-02	3.00	628.59	675.38	716.42	727.53	713.75	776.40	785.59	715.16
S3-TF-01	1.75	626.07	672.37	713.43	724.95	711.13	774.15	783.82	712.62
S3-BP-01	-1.63	596.47	641.32	681.45	696.23	683.65	744.74	755.43	683.04
S3-BP-02	-2.13	597.38	642.73	682.81	697.59	685.14	746.26	756.77	684.38
S3-BP-03	-2.63	597.63	643.26	683.19	697.87	685.74	746.83	757.19	684.81
S3-BP-04	-3.13	597.35	643.21	682.92	697.58	685.72	746.59	756.86	684.60
S3-BP-05	-3.63	596.80	642.82	682.31	696.95	685.28	745.63	755.80	683.95
S3-BP-06	-4.13	596.05	642.27	681.48	696.02	684.62	744.41	754.44	683.06
S3-BP-07	-4.63	595.36	641.74	680.61	695.07	683.99	743.20	753.08	682.18
S3-BF-01	-5.50	594.44	641.21	679.68	693.74	683.10	741.17	750.50	680.89
S3-BF-02	-6.75	592.90	639.86	677.86	690.82	680.62	737.26	745.32	678.19
S3-BF-03	-8.00	594.92	642.70	679.58	690.35	680.12	735.96	741.75	678.40
S3-BF-04	-9.25	590.24	637.52	672.71	681.42	671.88	725.75	729.59	670.49
S3-BF-05	-10.50	579.02	625.93	659.42	666.47	658.59	709.38	711.83	656.54
S3-BF-06	-11.75	563.73	610.24	642.10	647.21	640.77	687.89	689.44	638.21
S3-BF-07	-13.00	546.72	592.18	621.76	624.52	619.36	662.19	662.82	616.69
S3-BF-08	-14.25	532.01	575.95	603.83	603.98	600.04	639.09	638.03	597.35
S3-BF-09	-15.50	524.67	568.11	594.73	590.35	587.05	623.34	619.57	585.39
S3-BF-10	-16.75	526.19	572.59	598.96	589.35	585.68	620.58	613.05	585.33
S3-BF-11	-18.00	512.55	557.35	583.28	570.15	565.38	598.48	588.50	566.81
S3-BF-12	-19.25	488.71	529.54	555.11	540.26	534.94	564.56	553.71	537.11
S3-BF-13	-20.50	462.19	500.12	526.63	511.75	506.23	532.35	520.29	507.52
S3-BF-14	-21.75	428.22	462.48	490.96	477.42	472.72	495.87	483.34	471.95
S3-BP-08	-22.63	397.81	430.03	457.95	446.79	443.75	464.91	453.33	441.00
S3-BP-09	-23.13	382.08	415.03	444.78	436.85	436.17	456.08	446.15	429.76
S3-BP-10	-23.63	361.76	394.57	426.31	421.66	423.43	442.38	434.38	413.49

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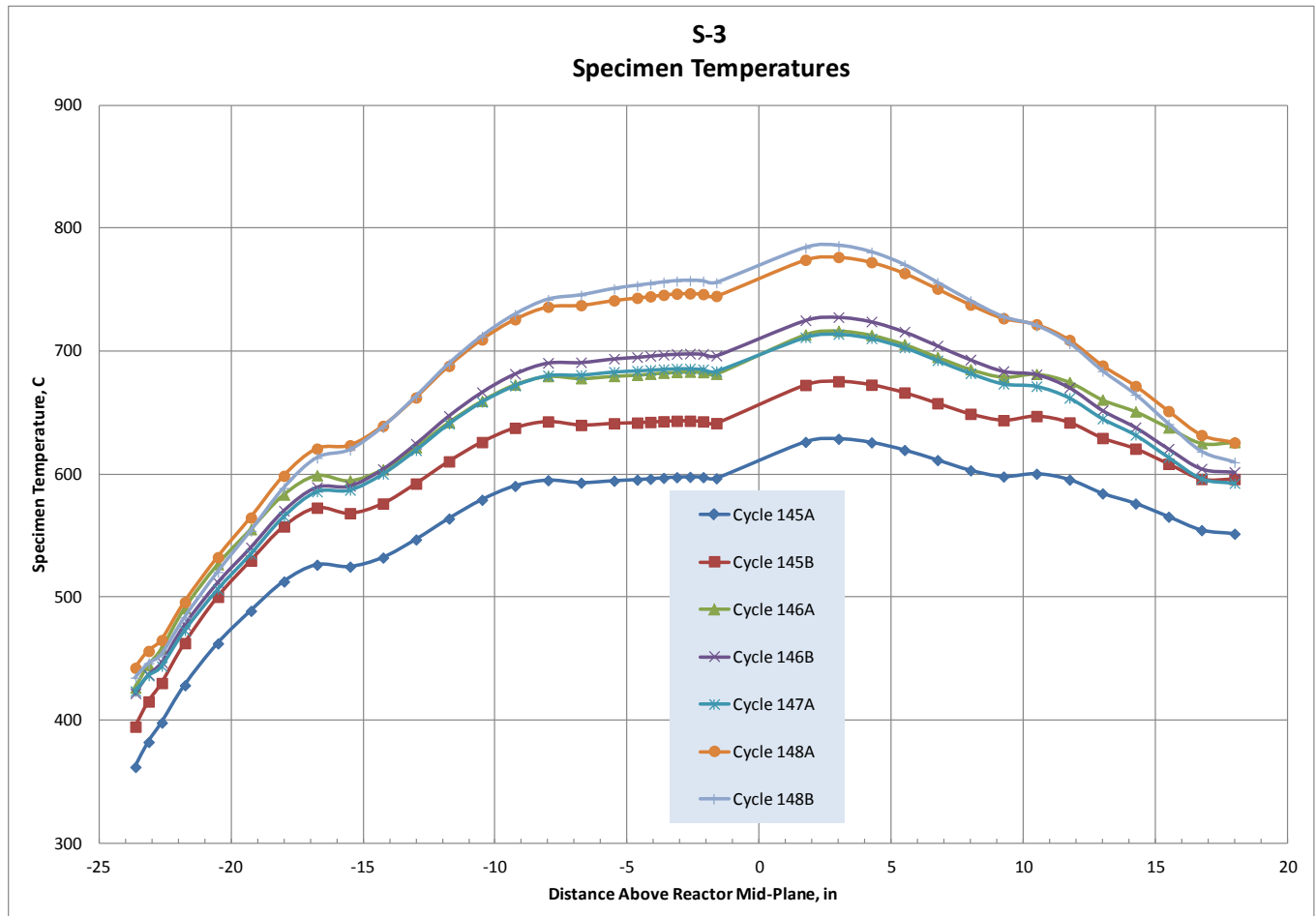


Figure 3. S-3 specimen axial temperature (°C) profile varying by ATR cycle.

Title: AGC-1 As Run Thermal Results

ECAR No.: 1944

Rev. No.: 0

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Date: 09/20/2012

Table 4. S-4 specimen temperatures (°C) with ATR cycle averages.

S-4									
ATR Stack # Naming	Elevation Above Mid-Plane	145A Average	145B Average	146A Average	146B Average	147A Average	148A Average	148B Average	AGC-1 Experiment Average
S4-TF-15	19.25	541.34	587.06	613.36	585.78	581.93	612.23	593.62	587.21
S4-TF-14	18.00	553.52	598.39	622.89	598.09	595.46	628.00	611.62	600.42
S4-TF-13	16.75	556.69	598.69	621.63	600.31	599.54	634.46	620.53	603.79
S4-TF-12	15.50	567.79	611.19	634.20	616.22	617.04	654.16	643.01	619.62
S4-TF-11	14.25	578.61	623.52	646.90	633.40	635.15	674.67	666.92	635.95
S4-TF-10	13.00	586.96	632.25	656.35	646.91	648.53	691.43	686.28	648.57
S4-TF-09	11.75	598.32	645.14	670.49	665.06	665.60	712.24	709.00	665.10
S4-TF-08	10.50	603.38	650.39	676.82	675.77	675.25	725.14	723.44	674.10
S4-TF-07	9.25	601.12	647.18	674.34	677.93	677.31	730.19	730.54	675.12
S4-TF-06	8.00	606.22	652.27	680.75	687.36	685.82	741.40	743.62	683.38
S4-TF-05	6.75	614.46	660.86	690.78	698.88	696.20	754.25	758.38	694.19
S4-TF-04	5.50	622.42	669.44	701.13	710.10	706.64	766.55	772.78	704.85
S4-TF-03	4.25	628.79	675.98	708.53	718.06	714.20	775.50	783.05	712.66
S4-TF-02	3.00	631.91	678.85	711.86	721.46	717.88	779.86	788.51	716.40
S4-TF-01	1.75	629.30	675.79	708.84	718.90	715.11	777.79	786.80	713.84
S4-BP-01	-1.63	599.63	644.54	676.54	689.99	687.55	748.45	758.42	684.15
S4-BP-02	-2.13	600.70	645.93	677.86	691.46	689.24	750.05	759.99	685.59
S4-BP-03	-2.63	600.97	646.55	678.33	691.91	689.82	750.42	760.53	686.06
S4-BP-04	-3.13	600.64	646.56	678.10	691.73	689.77	750.05	760.13	685.84
S4-BP-05	-3.63	599.98	646.09	677.45	691.03	689.29	749.11	758.98	685.13
S4-BP-06	-4.13	599.10	645.36	676.68	690.05	688.54	747.82	757.38	684.13
S4-BP-07	-4.63	598.32	644.81	675.93	689.15	687.81	746.49	755.70	683.18
S4-BF-01	-5.50	597.35	644.26	674.99	688.04	686.78	744.46	753.11	681.88
S4-BF-02	-6.75	595.70	642.88	673.06	685.22	684.18	740.43	748.05	679.15
S4-BF-03	-8.00	597.77	645.67	674.97	684.83	683.72	739.13	744.40	679.38
S4-BF-04	-9.25	593.04	640.49	668.07	676.09	675.40	728.95	732.18	671.46
S4-BF-05	-10.50	581.84	628.98	654.87	661.17	661.99	712.61	714.45	657.54
S4-BF-06	-11.75	566.68	613.56	637.45	641.97	644.35	691.23	692.06	639.30
S4-BF-07	-13.00	549.78	595.59	617.28	619.42	623.24	665.80	665.80	617.99
S4-BF-08	-14.25	535.00	579.37	599.64	598.99	603.84	642.54	640.92	598.65
S4-BF-09	-15.50	527.51	571.27	590.84	585.73	590.81	626.66	622.30	586.66
S4-BF-10	-16.75	528.85	575.62	595.48	585.22	589.22	623.58	615.61	586.57
S4-BF-11	-18.00	514.92	560.10	579.93	566.38	568.71	601.23	590.97	567.94
S4-BF-12	-19.25	490.84	532.14	552.04	536.90	537.95	567.25	555.98	538.18
S4-BF-13	-20.50	464.13	502.53	523.66	508.59	509.02	534.95	522.50	508.51
S4-BF-14	-21.75	430.00	464.71	488.25	474.44	475.40	498.33	485.40	472.89
S4-BP-08	-22.63	399.49	432.02	455.38	443.97	446.29	467.26	455.33	441.88
S4-BP-09	-23.13	383.91	417.12	441.91	433.71	438.90	458.80	448.43	430.72
S4-BP-10	-23.63	363.60	396.66	423.26	418.37	426.10	445.23	436.82	414.44

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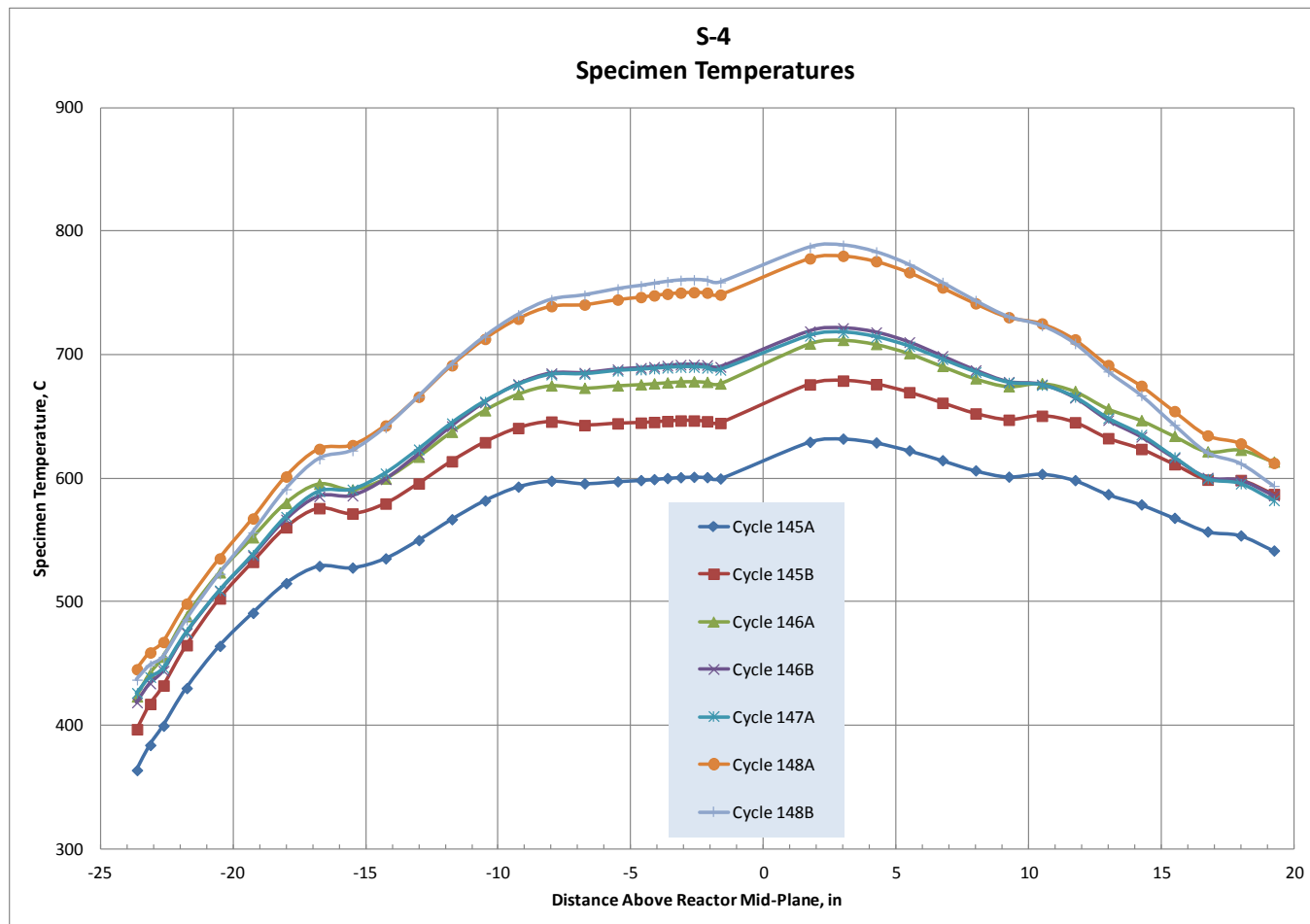


Figure 4. S-4 specimen axial temperature (°C) profile varying by ATR cycle.

Title: AGC-1 As Run Thermal Results

ECAR No.: 1944

Rev. No.: 0

Project No.: 23747

Date: 09/20/2012

Table 5. S-5 specimen temperatures (°C) with ATR cycle averages.

S-5									
ATR Stack # Naming	Elevation Above Mid-Plane	145A Average	145B Average	146A Average	146B Average	147A Average	148A Average	148B Average	AGC-1 Experiment Average
S5-TF-15	19.25	539.86	585.09	615.98	588.23	579.68	609.89	591.26	586.32
S5-TF-14	18.00	551.78	596.19	626.01	601.03	592.86	625.27	608.75	599.40
S5-TF-13	16.75	554.74	596.23	625.27	603.56	596.73	631.38	617.32	602.68
S5-TF-12	15.50	565.57	608.41	638.15	620.03	613.96	650.89	639.73	618.45
S5-TF-11	14.25	576.23	620.58	651.16	637.37	631.89	671.07	663.41	634.68
S5-TF-10	13.00	584.48	629.19	660.75	650.90	645.20	687.75	682.53	647.23
S5-TF-09	11.75	595.80	642.12	674.94	669.20	662.47	708.71	705.39	663.86
S5-TF-08	10.50	600.84	647.48	681.40	679.75	672.11	721.55	719.78	672.86
S5-TF-07	9.25	598.53	644.10	678.93	682.03	674.07	726.45	726.85	673.83
S5-TF-06	8.00	603.57	648.96	685.49	691.63	682.46	737.56	739.64	682.00
S5-TF-05	6.75	611.64	657.49	695.63	703.04	692.66	750.18	754.23	692.70
S5-TF-04	5.50	619.81	666.30	706.05	714.48	703.19	762.63	768.60	703.49
S5-TF-03	4.25	626.15	672.77	713.40	722.21	710.75	771.51	778.89	711.25
S5-TF-02	3.00	629.12	675.74	716.66	725.64	714.37	776.03	784.47	715.00
S5-TF-01	1.75	626.59	672.72	713.60	723.14	711.68	773.94	782.74	712.47
S5-BP-01	-1.63	597.25	641.84	681.28	694.49	684.51	744.82	754.77	683.06
S5-BP-02	-2.13	598.19	643.26	682.61	695.87	686.05	746.32	756.20	684.42
S5-BP-03	-2.63	598.52	643.75	683.03	696.26	686.60	746.72	756.63	684.85
S5-BP-04	-3.13	598.25	643.69	682.87	696.02	686.60	746.33	756.21	684.64
S5-BP-05	-3.63	597.56	643.15	682.26	695.36	686.25	745.30	755.07	683.92
S5-BP-06	-4.13	596.67	642.36	681.44	694.33	685.55	743.91	753.46	682.90
S5-BP-07	-4.63	595.76	641.69	680.69	693.48	684.80	742.58	751.78	681.91
S5-BF-01	-5.50	594.74	641.20	679.76	692.31	683.61	740.70	749.36	680.63
S5-BF-02	-6.75	593.31	639.96	677.92	689.41	680.96	736.79	744.20	677.95
S5-BF-03	-8.00	595.32	642.65	679.79	689.34	680.40	735.32	740.57	678.15
S5-BF-04	-9.25	590.54	637.57	673.19	680.76	671.93	725.15	728.27	670.27
S5-BF-05	-10.50	579.34	625.92	659.98	665.93	658.63	708.89	710.62	656.37
S5-BF-06	-11.75	564.18	610.64	642.35	646.48	641.17	687.66	688.43	638.17
S5-BF-07	-13.00	547.28	592.72	621.82	623.68	620.11	662.16	662.17	616.79
S5-BF-08	-14.25	532.56	576.58	603.88	603.11	600.78	638.91	637.39	597.43
S5-BF-09	-15.50	525.12	568.51	595.00	589.69	587.64	623.00	618.74	585.41
S5-BF-10	-16.75	526.40	572.65	599.44	589.16	585.93	619.82	611.91	585.19
S5-BF-11	-18.00	512.60	557.26	583.70	569.91	565.54	597.64	587.31	566.58
S5-BF-12	-19.25	488.75	529.44	555.47	540.29	535.13	563.82	552.66	536.93
S5-BF-13	-20.50	462.35	500.17	526.66	511.60	506.41	531.99	519.45	507.39
S5-BF-14	-21.75	428.40	462.71	490.95	477.08	473.02	495.68	482.62	471.89
S5-BP-08	-22.63	397.99	430.13	457.90	446.47	444.04	464.51	452.66	440.89
S5-BP-09	-23.13	382.28	415.09	444.76	436.53	436.35	455.66	445.47	429.63
S5-BP-10	-23.63	362.01	394.65	426.26	421.37	423.42	441.99	433.78	413.36

Title: AGC-1 As Run Thermal Results

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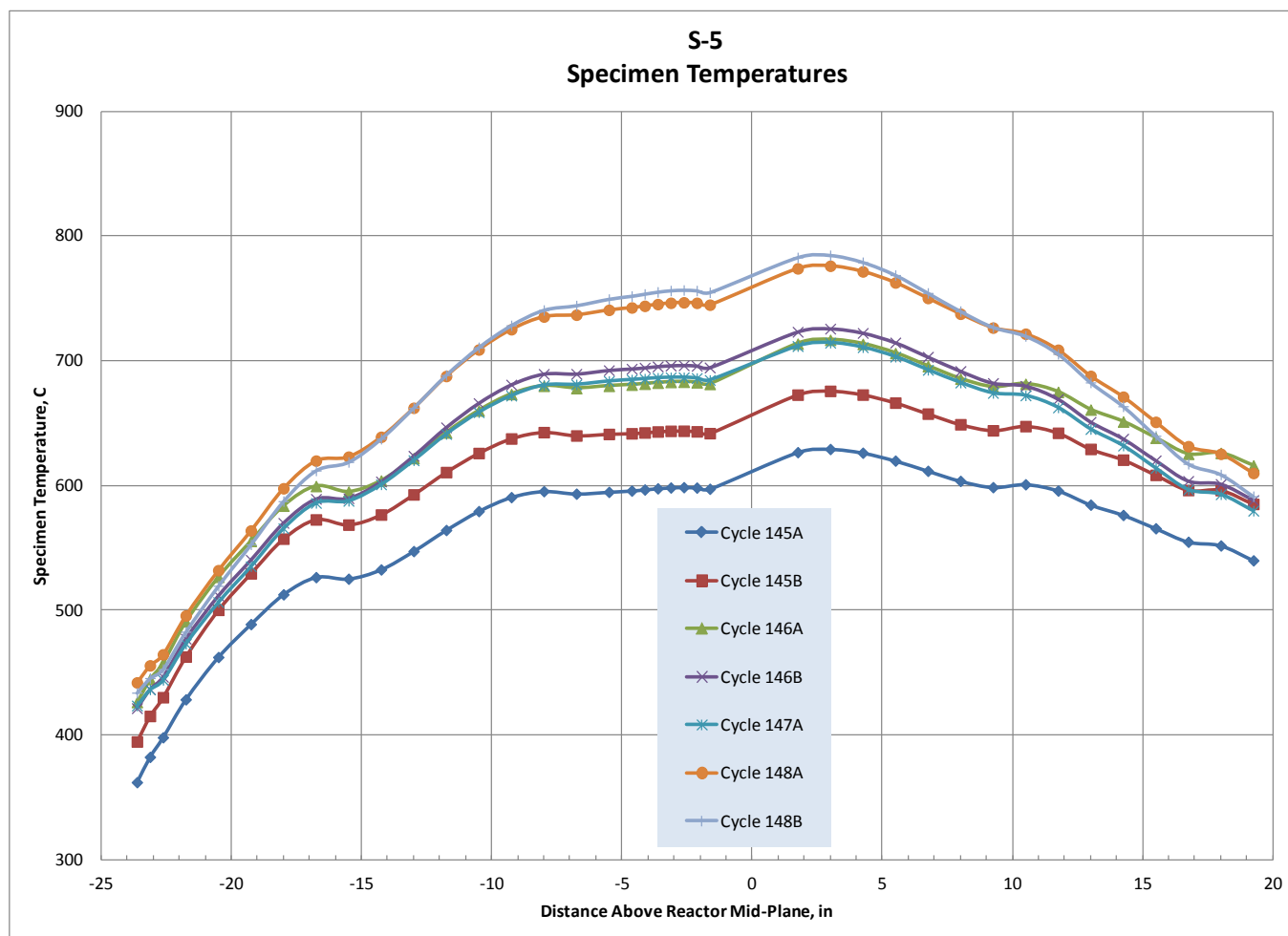


Figure 5. S-5 specimen axial temperature (°C) profile varying by ATR cycle.

Title: AGC-1 As Run Thermal Results

ECAR No.: 1944

Rev. No.: 0

Project No.: 23747

Date: 09/20/2012

Table 6. S-6 specimen temperatures (°C) with ATR cycle averages.

S-6										
ATR	Elevation								AGC-1	
Stack #	Above	145A	145B	146A	146B	147A	148A	148B	Experiment	
Naming	Mid-Plane	Average	Average	Average	Average	Average	Average	Average	Average	
S6-TF-15	19.25	536.27	580.64	620.94	593.23	574.70	604.96	586.61	584.25	
S6-TF-14	18.00	547.55	590.76	631.78	607.01	587.02	619.59	603.35	596.96	
S6-TF-13	16.75	549.91	590.14	631.60	610.36	590.05	624.94	611.27	599.89	
S6-TF-12	15.50	560.13	601.74	645.05	627.30	606.72	643.78	633.09	615.35	
S6-TF-11	14.25	570.32	613.44	658.55	645.10	624.26	663.71	656.27	631.38	
S6-TF-10	13.00	578.26	621.95	668.35	659.04	637.36	680.04	675.14	643.83	
S6-TF-09	11.75	589.35	634.71	682.67	677.55	654.38	700.70	697.63	660.31	
S6-TF-08	10.50	594.04	639.84	689.37	688.43	663.90	713.30	711.87	669.21	
S6-TF-07	9.25	591.59	636.33	687.13	690.91	665.65	718.15	718.76	670.13	
S6-TF-06	8.00	596.43	641.16	693.66	700.50	673.88	729.02	731.55	678.21	
S6-TF-05	6.75	604.49	649.68	703.86	711.91	684.21	741.50	745.99	688.89	
S6-TF-04	5.50	612.74	658.48	714.31	723.27	694.68	754.06	760.33	699.69	
S6-TF-03	4.25	619.14	664.97	721.47	731.23	702.16	762.97	770.74	707.47	
S6-TF-02	3.00	621.93	667.83	724.74	735.03	705.63	767.43	776.19	711.16	
S6-TF-01	1.75	619.27	664.85	721.87	732.27	703.11	765.44	774.43	708.65	
S6-BP-01	-1.63	590.24	634.07	689.33	703.60	676.11	736.12	746.71	679.32	
S6-BP-02	-2.13	591.08	635.44	690.63	704.86	677.64	737.52	747.95	680.59	
S6-BP-03	-2.63	591.36	635.97	691.06	705.20	678.18	737.79	748.26	680.98	
S6-BP-04	-3.13	591.17	635.89	690.96	705.00	678.14	737.43	747.89	680.79	
S6-BP-05	-3.63	590.54	635.48	690.47	704.33	677.85	736.63	746.88	680.18	
S6-BP-06	-4.13	589.73	634.89	689.64	703.35	677.29	735.49	745.52	679.30	
S6-BP-07	-4.63	588.90	634.25	688.86	702.52	676.47	734.20	744.07	678.35	
S6-BF-01	-5.50	587.96	633.76	687.90	701.14	675.33	732.36	741.60	677.06	
S6-BF-02	-6.75	586.65	632.54	685.91	698.22	672.84	728.58	736.43	674.42	
S6-BF-03	-8.00	588.47	634.99	687.95	698.10	672.16	726.93	732.54	674.49	
S6-BF-04	-9.25	583.66	629.78	681.23	689.57	663.53	716.66	720.25	666.54	
S6-BF-05	-10.50	572.34	618.09	668.11	674.64	650.07	700.31	702.59	652.58	
S6-BF-06	-11.75	557.34	602.65	650.35	655.01	632.79	679.15	680.55	634.40	
S6-BF-07	-13.00	540.70	585.07	629.75	632.05	611.97	653.99	654.48	613.20	
S6-BF-08	-14.25	526.18	569.05	611.40	611.31	592.82	630.98	629.93	593.90	
S6-BF-09	-15.50	519.04	561.17	602.25	597.60	580.05	615.18	611.39	581.97	
S6-BF-10	-16.75	520.75	565.80	606.48	596.55	578.67	612.36	604.99	581.96	
S6-BF-11	-18.00	507.48	550.95	590.27	576.82	558.72	590.76	580.85	563.61	
S6-BF-12	-19.25	484.18	523.69	561.59	546.62	528.81	557.51	546.78	534.25	
S6-BF-13	-20.50	458.19	494.80	532.43	517.55	500.60	526.13	513.98	504.94	
S6-BF-14	-21.75	424.70	458.11	496.15	482.58	467.63	490.36	477.69	469.71	
S6-BP-08	-22.63	394.61	425.90	462.91	451.68	438.74	459.44	447.65	438.80	
S6-BP-09	-23.13	378.63	410.46	450.22	442.17	430.33	449.87	439.69	427.23	
S6-BP-10	-23.63	358.25	389.87	431.77	427.06	417.07	435.77	427.73	410.79	

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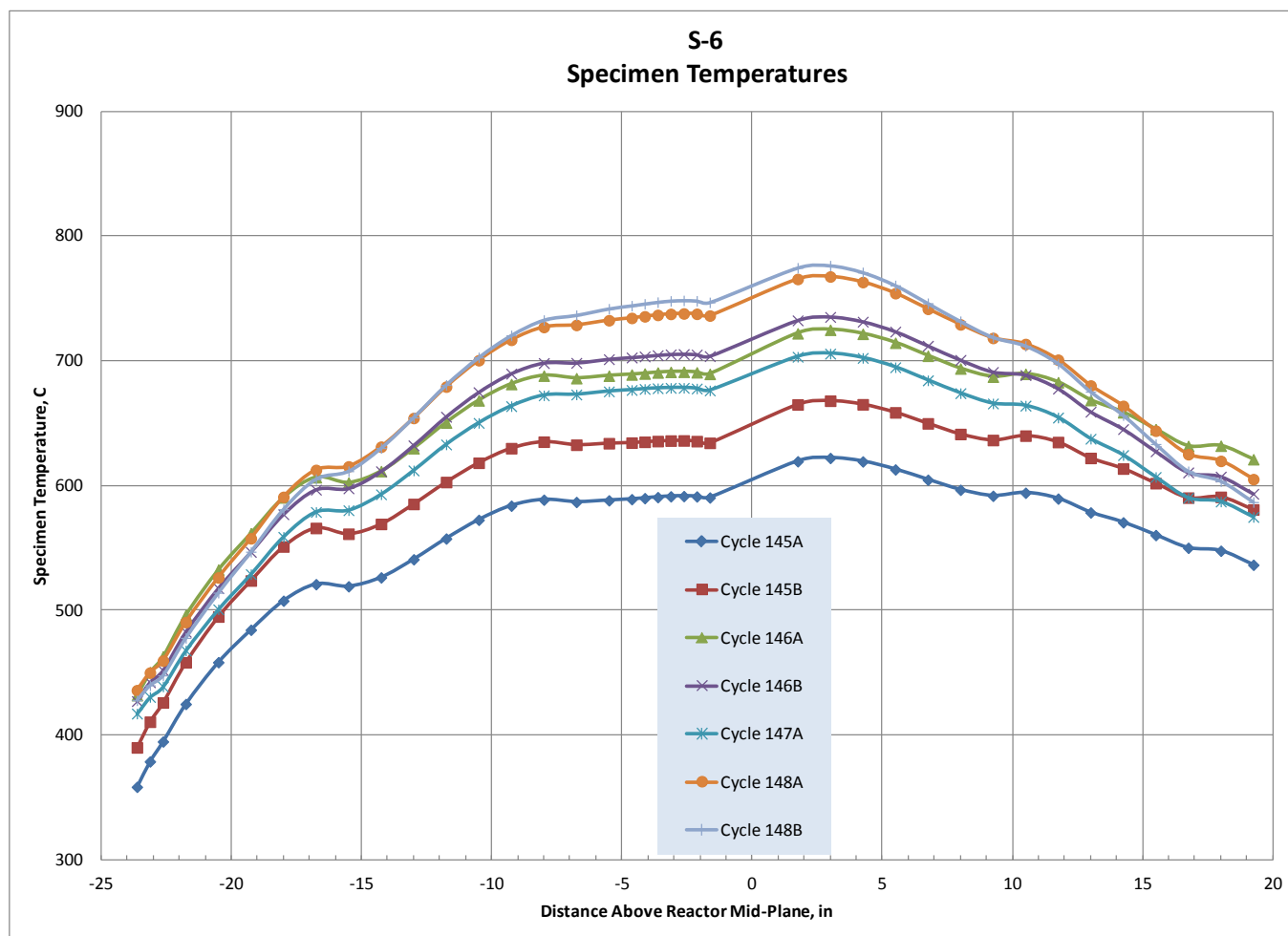


Figure 6. S-6 specimen axial temperature (°C) profile varying by ATR cycle.

Title: AGC-1 As Run Thermal Results

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Table 7. S-7 specimen temperatures (°C) with ATR cycle averages.

S-7 (1 of 5)										
ATR Stack # Naming	Elevation Above Mid- Plane	145A Average	145B Average	146A Average	146B Average	147A Average	148A Average	148B Average	AGC-1 Experiment Average	
S7-TP-76	18.875	560.99	611.59	649.50	624.08	609.50	640.17	622.84	615.78	
S7-TP-75	18.625	564.09	614.85	652.55	627.69	612.92	644.01	627.10	619.26	
S7-TP-74	18.375	566.92	617.84	655.34	631.25	616.36	647.93	631.59	622.68	
S7-TP-73	18.125	569.07	619.87	657.18	633.88	618.89	650.94	635.11	625.19	
S7-TP-72	17.875	570.77	621.30	658.41	635.93	620.90	653.45	638.13	627.16	
S7-TP-71	17.625	572.09	622.27	659.19	637.37	622.32	655.32	640.40	628.59	
S7-TP-70	17.375	573.42	623.35	660.13	638.98	623.97	657.42	642.94	630.18	
S7-TP-69	17.125	574.98	624.70	661.41	641.07	626.14	660.08	646.19	632.21	
S7-TP-68	16.875	576.71	626.34	663.09	643.48	628.67	663.06	649.75	634.55	
S7-TP-67	16.625	578.69	628.38	665.23	646.28	631.60	666.43	653.71	637.27	
S7-TP-66	16.375	580.42	630.03	666.99	648.41	633.71	668.90	656.51	639.34	
S7-TP-65	16.125	582.83	632.74	669.88	651.93	637.25	672.85	660.97	642.67	
S7-TP-64	15.875	585.71	636.10	673.50	656.38	641.78	677.81	666.58	646.83	
S7-TP-63	15.625	588.62	639.47	677.11	660.79	646.28	682.71	672.09	650.96	
S7-TP-62	15.375	591.56	642.84	680.69	665.19	650.76	687.61	677.61	655.09	
S7-TP-61	15.125	594.51	646.13	684.19	669.56	655.19	692.45	683.10	659.17	
S7-TP-60	14.875	597.38	649.27	687.54	673.84	659.46	697.13	688.43	663.12	
S7-TP-59	14.625	599.97	652.10	690.55	677.76	663.35	701.46	693.40	666.73	
S7-TP-58	14.375	602.26	654.54	693.22	681.28	666.79	705.41	697.96	669.96	
S7-TP-57	14.125	604.33	656.71	695.62	684.50	669.92	709.10	702.23	672.91	
S7-TP-56	13.875	606.33	658.82	697.95	687.64	672.95	712.74	706.40	675.79	
S7-TP-55	13.625	608.40	661.00	700.39	690.88	676.05	716.48	710.64	678.75	
S7-TP-54	13.375	610.60	663.34	703.00	694.27	679.27	720.37	714.99	681.86	
S7-TP-53	13.125	612.93	665.84	705.80	697.84	682.62	724.39	719.45	685.11	
S7-TP-52	12.875	615.38	668.49	708.74	701.59	686.06	728.55	724.06	688.50	
S7-TP-51	12.625	617.94	671.24	711.79	705.48	689.62	732.88	728.78	692.01	
S7-TP-50	12.375	620.59	674.08	714.91	709.50	693.27	737.30	733.55	695.61	
S7-TP-49	12.125	623.20	676.88	718.01	713.48	696.87	741.64	738.23	699.15	
S7-TP-48	11.875	625.60	679.48	720.90	717.21	700.21	745.72	742.61	702.45	
S7-TP-47	11.625	627.71	681.80	723.48	720.61	703.24	749.49	746.65	705.45	
S7-TP-46	11.375	629.47	683.71	725.68	723.65	705.95	752.89	750.33	708.08	
S7-TP-45	11.125	630.89	685.22	727.48	726.28	708.25	755.88	753.64	710.32	
S7-TP-44	10.875	631.93	686.27	728.83	728.46	710.16	758.43	756.51	712.13	
S7-TP-43	10.625	632.57	686.84	729.67	730.17	711.64	760.52	758.94	713.49	
S7-TP-42	10.375	632.84	686.98	730.04	731.48	712.73	762.20	761.02	714.44	
S7-TP-41	10.125	632.90	686.84	730.14	732.52	713.59	763.66	762.91	715.16	
S7-TP-40	9.875	632.94	686.60	730.18	733.56	714.43	765.11	764.82	715.84	
S7-TP-39	9.625	633.10	686.49	730.27	734.53	715.20	766.41	766.51	716.50	
S7-TP-38	9.375	633.61	686.93	730.90	735.94	716.44	768.20	768.62	717.63	
S7-TP-37	9.125	634.34	687.66	731.83	737.72	718.03	770.38	771.20	719.10	
S7-TP-36	8.875	635.28	688.57	733.00	739.62	719.71	772.64	773.83	720.71	
S7-TP-35	8.625	636.46	689.70	734.42	741.70	721.51	775.02	776.60	722.50	
S7-TP-34	8.375	637.81	691.03	736.07	743.89	723.40	777.52	779.50	724.44	
S7-TP-33	8.125	639.26	692.50	737.88	746.11	725.36	780.01	782.41	726.46	

Title: AGC-1 As Run Thermal Results

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S-7 (2 of 5)									
ATR Stack # Naming	Elevation Above Mid- Plane	145A Average	145B Average	146A Average	146B Average	147A Average	148A Average	148B Average	AGC-1 Experiment Average
S7-TP-32	7.875	640.82	694.08	739.79	748.37	727.38	782.51	785.34	728.55
S7-TP-31	7.625	642.48	695.77	741.79	750.69	729.47	785.06	788.32	730.71
S7-TP-30	7.375	644.22	697.56	743.88	753.04	731.61	787.65	791.35	732.94
S7-TP-29	7.125	646.03	699.40	746.07	755.45	733.82	790.31	794.43	735.24
S7-TP-28	6.875	647.87	701.29	748.29	757.92	736.05	792.99	797.48	737.55
S7-TP-27	6.625	649.73	703.21	750.50	760.38	738.27	795.67	800.51	739.88
S7-TP-26	6.375	651.61	705.16	752.74	762.83	740.46	798.37	803.54	742.21
S7-TP-25	6.125	653.46	707.07	754.96	765.26	742.62	801.02	806.53	744.51
S7-TP-24	5.875	655.25	708.93	757.10	767.58	744.75	803.54	809.39	746.72
S7-TP-23	5.625	656.96	710.67	759.12	769.77	746.76	805.88	812.11	748.81
S7-TP-22	5.375	658.57	712.27	760.98	771.79	748.61	808.05	814.65	750.75
S7-TP-21	5.125	660.05	713.77	762.69	773.65	750.31	810.08	816.97	752.54
S7-TP-20	4.875	661.44	715.17	764.26	775.32	751.88	812.00	819.14	754.20
S7-TP-19	4.625	662.71	716.41	765.67	776.85	753.32	813.75	821.14	755.71
S7-TP-18	4.375	663.83	717.47	766.89	778.22	754.60	815.30	822.93	757.04
S7-TP-17	4.125	664.79	718.38	767.93	779.42	755.71	816.61	824.47	758.18
S7-TP-16	3.875	665.59	719.18	768.81	780.44	756.67	817.70	825.84	759.16
S7-TP-15	3.625	666.24	719.84	769.57	781.28	757.44	818.65	827.05	759.99
S7-TP-14	3.375	666.72	720.32	770.18	781.93	758.03	819.43	828.05	760.65
S7-TP-13	3.125	667.00	720.60	770.57	782.35	758.42	819.95	828.77	761.07
S7-TP-12	2.875	667.03	720.61	770.67	782.47	758.53	820.22	829.18	761.22
S7-TP-11	2.625	666.81	720.33	770.44	782.31	758.33	820.21	829.25	761.07
S7-TP-10	2.375	666.27	719.75	769.87	781.81	757.83	819.81	828.96	760.58
S7-TP-09	2.125	665.29	718.75	768.86	780.88	756.98	818.99	828.23	759.68
S7-TP-08	1.875	663.75	717.19	767.28	779.41	755.60	817.63	826.94	758.22
S7-TP-07	1.625	661.43	714.85	764.93	777.23	753.50	815.53	824.91	756.01
S7-TP-06	1.375	658.17	711.52	761.54	774.04	750.49	812.47	821.93	752.83
S7-TP-05	1.125	654.00	707.20	757.10	769.82	746.55	808.42	817.97	748.67
S7-TP-04	0.875	649.50	702.44	752.22	765.14	742.15	803.89	813.55	744.08
S7-TP-03	0.625	645.37	698.04	747.66	760.76	738.04	799.61	809.38	739.79
S7-TP-02	0.375	642.04	694.43	743.86	757.21	734.60	796.04	805.94	736.26
S7-TP-01	0.125	639.54	691.66	740.85	754.57	731.93	793.24	803.27	733.53
S7-BP-01	-0.125	637.75	689.54	738.54	752.64	729.95	791.09	801.20	731.48
S7-BP-02	-0.375	636.58	688.08	736.97	751.47	728.73	789.67	799.86	730.14
S7-BP-03	-0.625	636.05	687.47	736.33	751.11	728.40	789.14	799.43	729.65
S7-BP-04	-0.875	635.99	687.57	736.41	751.41	728.79	789.31	799.68	729.81
S7-BP-05	-1.125	636.21	688.07	736.88	752.06	729.54	789.87	800.28	730.34
S7-BP-06	-1.375	636.60	688.73	737.53	752.84	730.40	790.58	801.00	731.02
S7-BP-07	-1.625	637.02	689.39	738.16	753.56	731.21	791.32	801.67	731.67
S7-BP-08	-1.875	637.35	689.91	738.69	754.16	731.90	791.94	802.23	732.22
S7-BP-09	-2.125	637.60	690.34	739.09	754.58	732.41	792.38	802.64	732.62
S7-BP-10	-2.375	637.72	690.64	739.36	754.81	732.77	792.61	802.88	732.87
S7-BP-11	-2.625	637.71	690.80	739.46	754.86	732.95	792.66	802.97	732.96
S7-BP-12	-2.875	637.62	690.84	739.39	754.79	732.98	792.56	802.86	732.92

ENGINEERING CALCULATIONS AND ANALYSIS

Title: AGC-1 As Run Thermal Results

ECAR No.: 1944

Rev. No.: 0

Project No.: 23747

Date: 09/20/2012

S-7 (3 of 5)										
ATR	Elevation								AGC-1	
Stack #	Above	145A	145B	146A	146B	147A	148A	148B	Experiment	
Naming	Mid-Plane	Average	Average	Average	Average	Average	Average	Average	Average	
S7-TP-13	3.125	667.00	720.60	770.57	782.35	758.42	819.95	828.77	761.07	
S7-TP-12	2.875	667.03	720.61	770.67	782.47	758.53	820.22	829.18	761.22	
S7-TP-11	2.625	666.81	720.33	770.44	782.31	758.33	820.21	829.25	761.07	
S7-TP-10	2.375	666.27	719.75	769.87	781.81	757.83	819.81	828.96	760.58	
S7-TP-09	2.125	665.29	718.75	768.86	780.88	756.98	818.99	828.23	759.68	
S7-TP-08	1.875	663.75	717.19	767.28	779.41	755.60	817.63	826.94	758.22	
S7-TP-07	1.625	661.43	714.85	764.93	777.23	753.50	815.53	824.91	756.01	
S7-TP-06	1.375	658.17	711.52	761.54	774.04	750.49	812.47	821.93	752.83	
S7-TP-05	1.125	654.00	707.20	757.10	769.82	746.55	808.42	817.97	748.67	
S7-TP-04	0.875	649.50	702.44	752.22	765.14	742.15	803.89	813.55	744.08	
S7-TP-03	0.625	645.37	698.04	747.66	760.76	738.04	799.61	809.38	739.79	
S7-TP-02	0.375	642.04	694.43	743.86	757.21	734.60	796.04	805.94	736.26	
S7-TP-01	0.125	639.54	691.66	740.85	754.57	731.93	793.24	803.27	733.53	
S7-BP-01	-0.125	637.75	689.54	738.54	752.64	729.95	791.09	801.20	731.48	
S7-BP-02	-0.375	636.58	688.08	736.97	751.47	728.73	789.67	799.86	730.14	
S7-BP-03	-0.625	636.05	687.47	736.33	751.11	728.40	789.14	799.43	729.65	
S7-BP-04	-0.875	635.99	687.57	736.41	751.41	728.79	789.31	799.68	729.81	
S7-BP-05	-1.125	636.21	688.07	736.88	752.06	729.54	789.87	800.28	730.34	
S7-BP-06	-1.375	636.60	688.73	737.53	752.84	730.40	790.58	801.00	731.02	
S7-BP-07	-1.625	637.02	689.39	738.16	753.56	731.21	791.32	801.67	731.67	
S7-BP-08	-1.875	637.35	689.91	738.69	754.16	731.90	791.94	802.23	732.22	
S7-BP-09	-2.125	637.60	690.34	739.09	754.58	732.41	792.38	802.64	732.62	
S7-BP-10	-2.375	637.72	690.64	739.36	754.81	732.77	792.61	802.88	732.87	
S7-BP-11	-2.625	637.71	690.80	739.46	754.86	732.95	792.66	802.97	732.96	
S7-BP-12	-2.875	637.62	690.84	739.39	754.79	732.98	792.56	802.86	732.92	
S7-BP-13	-3.125	637.44	690.75	739.22	754.62	732.88	792.29	802.54	732.73	
S7-BP-14	-3.375	637.17	690.59	738.98	754.32	732.68	791.91	802.06	732.44	
S7-BP-15	-3.625	636.84	690.37	738.68	753.93	732.42	791.40	801.48	732.08	
S7-BP-16	-3.875	636.45	690.07	738.28	753.45	732.11	790.77	800.80	731.63	
S7-BP-17	-4.125	636.00	689.73	737.84	752.94	731.78	790.11	800.07	731.14	
S7-BP-18	-4.375	635.53	689.41	737.37	752.41	731.42	789.45	799.25	730.62	
S7-BP-19	-4.625	635.05	689.10	736.90	751.90	731.04	788.80	798.39	730.10	
S7-BP-20	-4.875	634.60	688.77	736.45	751.39	730.61	788.12	797.52	729.58	
S7-BP-21	-5.125	634.17	688.44	736.02	750.82	730.15	787.39	796.62	729.03	
S7-BP-22	-5.375	633.73	688.07	735.51	750.12	729.62	786.58	795.62	728.42	
S7-BP-23	-5.625	633.24	687.66	734.90	749.35	729.01	785.69	794.52	727.73	
S7-BP-24	-5.875	632.75	687.24	734.29	748.56	728.37	784.74	793.39	727.03	
S7-BP-25	-6.125	632.29	686.82	733.74	747.78	727.75	783.79	792.25	726.34	
S7-BP-26	-6.375	631.91	686.46	733.33	747.09	727.16	782.92	791.14	725.72	
S7-BP-27	-6.625	631.64	686.26	733.06	746.53	726.62	782.18	790.09	725.21	
S7-BP-28	-6.875	631.55	686.23	732.95	746.09	726.18	781.55	789.08	724.83	
S7-BP-29	-7.125	631.58	686.33	732.93	745.74	725.81	780.98	788.08	724.53	
S7-BP-30	-7.375	631.68	686.53	732.97	745.41	725.44	780.43	787.06	724.27	
S7-BP-31	-7.625	631.75	686.72	732.95	744.95	724.98	779.79	785.94	723.94	

ENGINEERING CALCULATIONS AND ANALYSIS

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S-7 (4 of 5)									
ATR Stack # Naming	Elevation Above Mid- Plane	145A Average	145B Average	146A Average	146B Average	147A Average	148A Average	148B Average	AGC-1 Experiment Average
S7-BP-32	-7.875	631.62	686.67	732.67	744.25	724.29	778.90	784.53	723.37
S7-BP-33	-8.125	631.17	686.25	731.99	743.19	723.24	777.58	782.75	722.43
S7-BP-34	-8.375	630.34	685.40	730.86	741.73	721.77	775.81	780.58	721.06
S7-BP-35	-8.625	629.18	684.21	729.36	739.86	719.95	773.65	778.04	719.34
S7-BP-36	-8.875	627.75	682.74	727.53	737.68	717.90	771.20	775.20	717.32
S7-BP-37	-9.125	626.05	680.99	725.45	735.23	715.67	768.50	772.17	715.07
S7-BP-38	-9.375	624.09	679.02	723.15	732.55	713.26	765.58	768.97	712.61
S7-BP-39	-9.625	621.91	676.81	720.65	729.67	710.70	762.45	765.58	709.93
S7-BP-40	-9.875	619.53	674.38	717.94	726.63	707.99	759.13	761.99	707.08
S7-BP-41	-10.125	616.98	671.77	715.06	723.46	705.14	755.63	758.22	704.05
S7-BP-42	-10.375	614.27	668.97	711.99	720.10	702.11	751.96	754.30	700.84
S7-BP-43	-10.625	611.35	666.00	708.73	716.52	698.92	748.07	750.17	697.45
S7-BP-44	-10.875	608.27	662.89	705.28	712.71	695.55	743.97	745.83	693.86
S7-BP-45	-11.125	605.04	659.68	701.66	708.69	691.99	739.64	741.32	690.11
S7-BP-46	-11.375	601.68	656.35	697.92	704.51	688.22	735.10	736.63	686.19
S7-BP-47	-11.625	598.22	652.89	694.03	700.21	684.28	730.38	731.77	682.13
S7-BP-48	-11.875	594.63	649.25	689.94	695.70	680.13	725.42	726.65	677.87
S7-BP-49	-12.125	590.87	645.41	685.63	690.99	675.82	720.22	721.30	673.40
S7-BP-50	-12.375	587.00	641.50	681.24	686.16	671.39	714.90	715.81	668.83
S7-BP-51	-12.625	583.23	637.65	676.94	681.37	667.01	709.68	710.38	664.33
S7-BP-52	-12.875	579.59	633.90	672.70	676.68	662.72	704.59	705.03	659.93
S7-BP-53	-13.125	576.07	630.24	668.50	672.09	658.49	699.58	699.76	655.61
S7-BP-54	-13.375	572.66	626.64	664.43	667.59	654.30	694.60	694.56	651.36
S7-BP-55	-13.625	569.41	623.14	660.50	663.21	650.24	689.71	689.41	647.23
S7-BP-56	-13.875	566.32	619.79	656.78	658.99	646.31	685.01	684.36	643.25
S7-BP-57	-14.125	563.42	616.63	653.31	654.92	642.50	680.52	679.42	639.46
S7-BP-58	-14.375	560.73	613.66	650.06	650.97	638.79	676.17	674.59	635.81
S7-BP-59	-14.625	558.24	610.91	647.03	647.07	635.09	671.88	669.77	632.29
S7-BP-60	-14.875	555.98	608.44	644.28	643.27	631.49	667.71	665.02	628.94
S7-BP-61	-15.125	554.58	607.14	642.84	641.15	629.56	665.36	662.34	627.07
S7-BP-62	-15.375	553.48	606.31	641.83	639.25	627.81	663.16	659.66	625.47
S7-BP-63	-15.625	552.60	605.71	641.07	637.33	626.02	660.92	656.74	623.92
S7-BP-64	-15.875	552.07	605.55	640.77	635.90	624.69	659.25	654.36	622.84
S7-BP-65	-16.125	551.61	605.54	640.63	634.69	623.50	657.79	652.16	621.92
S7-BP-66	-16.375	550.92	605.27	640.24	633.32	622.07	656.15	649.78	620.79
S7-BP-67	-16.625	549.76	604.39	639.24	631.44	620.09	653.92	646.86	619.10
S7-BP-68	-16.875	547.98	602.70	637.40	628.77	617.31	650.86	643.16	616.62
S7-BP-69	-17.125	545.45	600.01	634.56	625.11	613.52	646.75	638.46	613.18
S7-BP-70	-17.375	542.21	596.40	630.80	620.54	608.82	641.75	632.89	608.87
S7-BP-71	-17.625	539.12	593.24	627.53	616.80	605.08	637.69	628.57	605.27
S7-BP-72	-17.875	534.96	588.49	622.65	611.29	599.48	631.67	622.20	599.97
S7-BP-73	-18.125	530.32	583.07	617.12	605.17	593.29	625.01	615.27	594.08
S7-BP-74	-18.375	525.30	577.14	611.10	598.66	586.73	617.87	607.96	587.76
S7-BP-75	-18.625	519.82	570.50	604.44	591.58	579.57	610.06	599.99	580.82

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S-7 (5 of 5)									
ATR Stack # Naming	Elevation Above Mid- Plane	145A Average	145B Average	146A Average	146B Average	147A Average	148A Average	148B Average	AGC-1 Experiment Average
S7-BP-76	-18.875	514.78	564.75	598.71	585.68	573.68	603.56	593.43	574.93
S7-BP-77	-19.125	509.73	559.14	593.05	579.93	568.03	597.28	587.04	569.17
S7-BP-78	-19.375	503.79	552.13	585.96	572.66	560.87	589.30	578.81	561.95
S7-BP-79	-19.625	497.66	544.93	578.73	565.35	553.64	581.30	570.47	554.62
S7-BP-80	-19.875	491.35	537.42	571.29	557.91	546.21	573.13	561.90	547.09
S7-BP-81	-20.125	486.56	532.59	566.70	553.53	541.95	568.44	557.11	542.45
S7-BP-82	-20.375	480.77	526.19	560.67	547.66	536.24	562.18	550.66	536.37
S7-BP-83	-20.625	473.80	517.87	552.83	539.92	528.69	553.98	542.18	528.50
S7-BP-84	-20.875	466.43	508.94	544.53	531.78	520.81	545.43	533.41	520.22
S7-BP-85	-21.125	458.64	499.17	535.56	522.97	512.34	536.29	524.02	511.30
S7-BP-86	-21.375	452.62	492.80	529.89	517.65	507.42	530.96	518.72	505.71
S7-BP-87	-21.625	445.48	485.01	522.25	510.47	500.64	523.64	511.45	498.40
S7-BP-88	-21.875	437.31	475.72	512.70	501.41	492.03	514.35	502.27	489.38
S7-BP-89	-22.125	429.61	467.05	503.81	493.08	484.22	505.91	494.06	481.09
S7-BP-90	-22.375	423.08	459.56	496.17	486.14	477.75	498.86	487.29	474.10
S7-BP-91	-22.625	419.31	455.20	491.91	482.74	474.73	495.27	484.01	470.41
S7-BP-92	-22.875	422.00	459.01	497.09	489.04	481.26	501.27	490.30	475.57
S7-BP-93	-23.125	431.65	472.42	514.11	507.40	499.83	519.60	508.83	491.62
S7-BP-94	-23.375	438.76	482.29	526.55	520.66	513.18	532.86	522.15	503.28
S7-BP-95	-23.625	442.22	487.10	532.60	527.07	519.62	539.25	528.54	508.91

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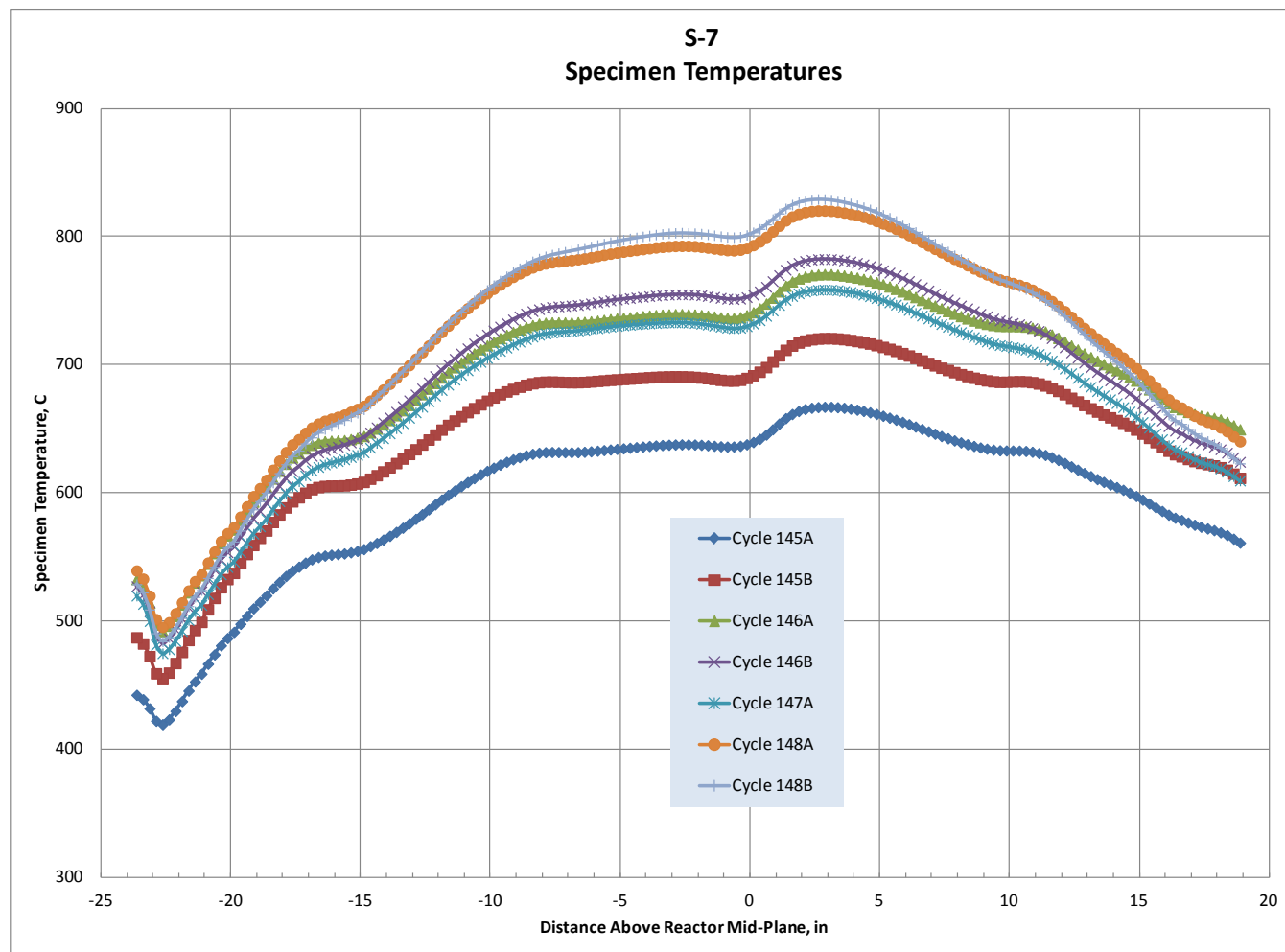


Figure 7. S-7 specimen axial temperature (°C) profile varying by ATR cycle.

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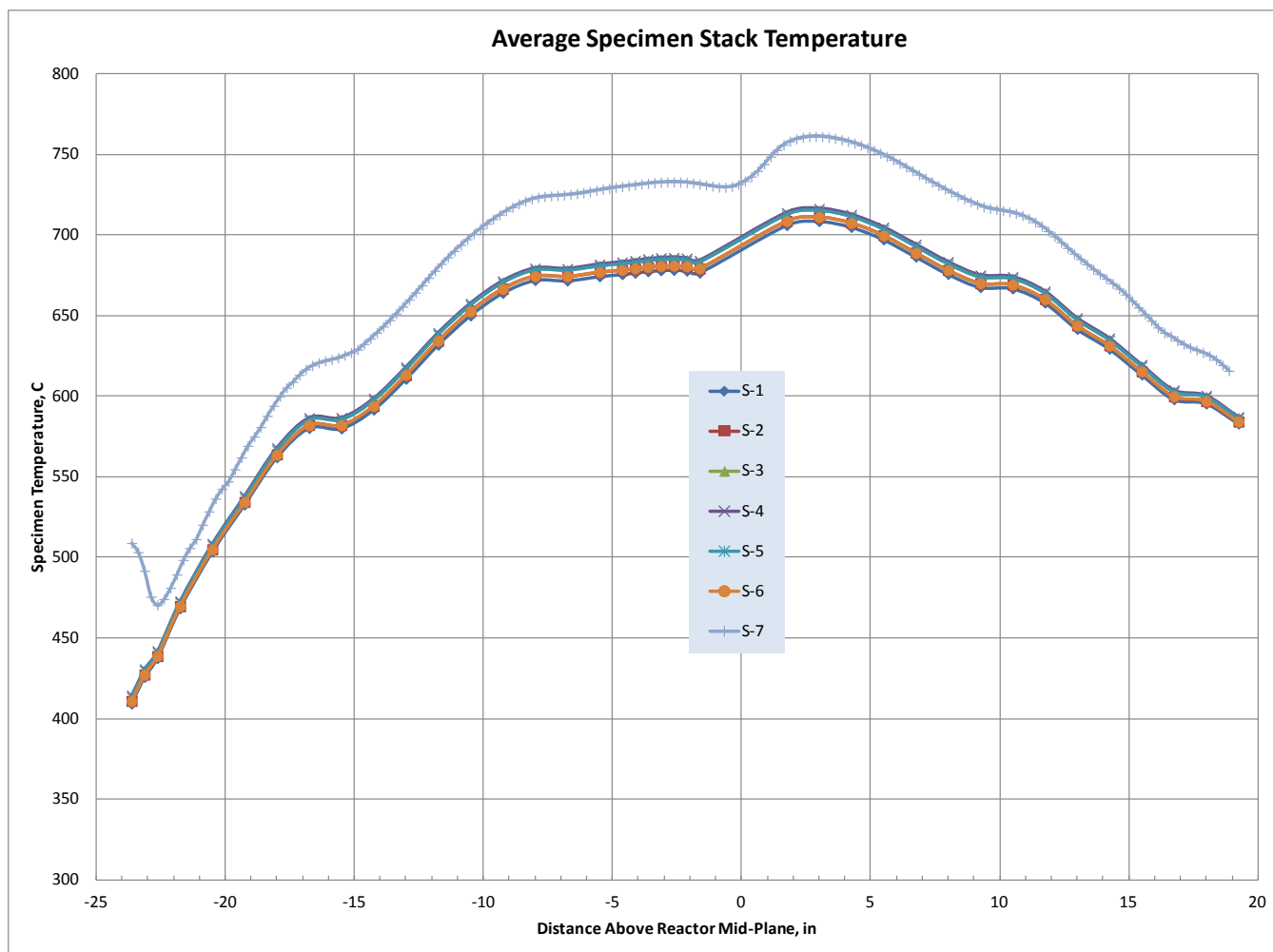


Figure 8. Average specimen stack temperature (°C).

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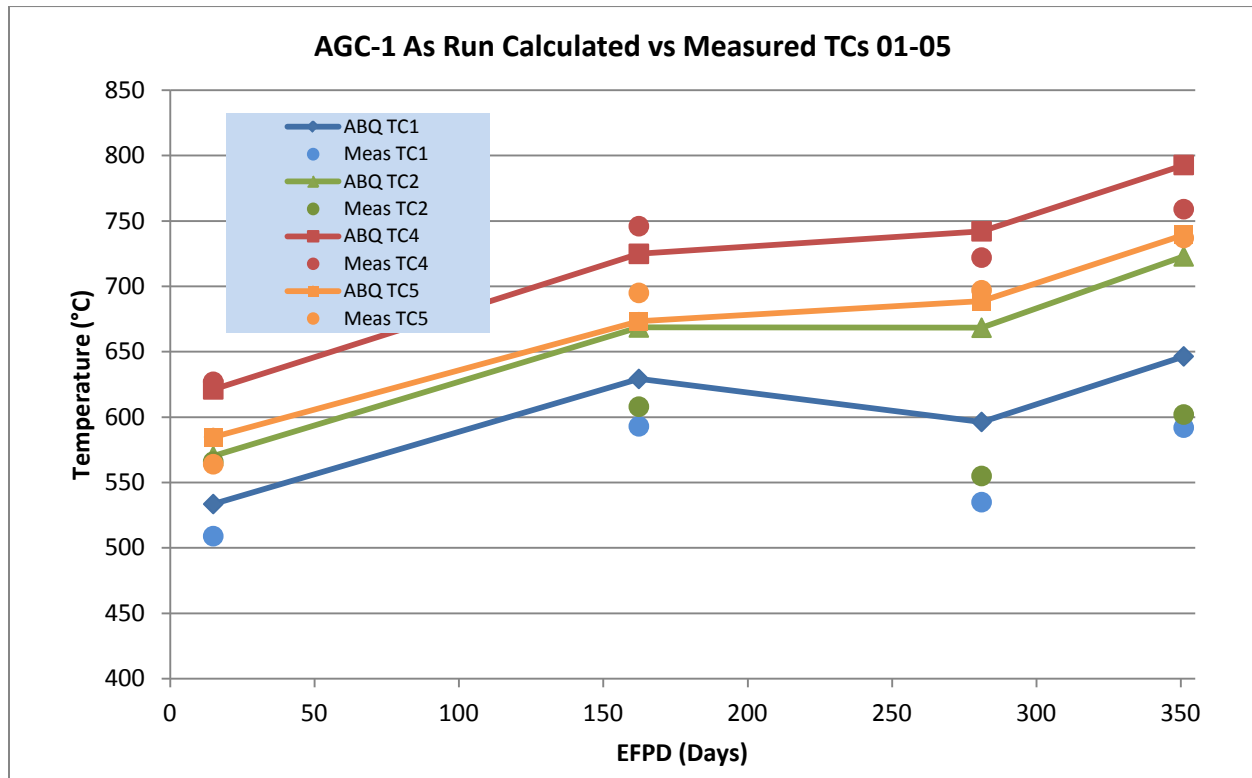


Figure 9. Calculated and measured TC temperatures compared for TCs 1,2,4, and 5.

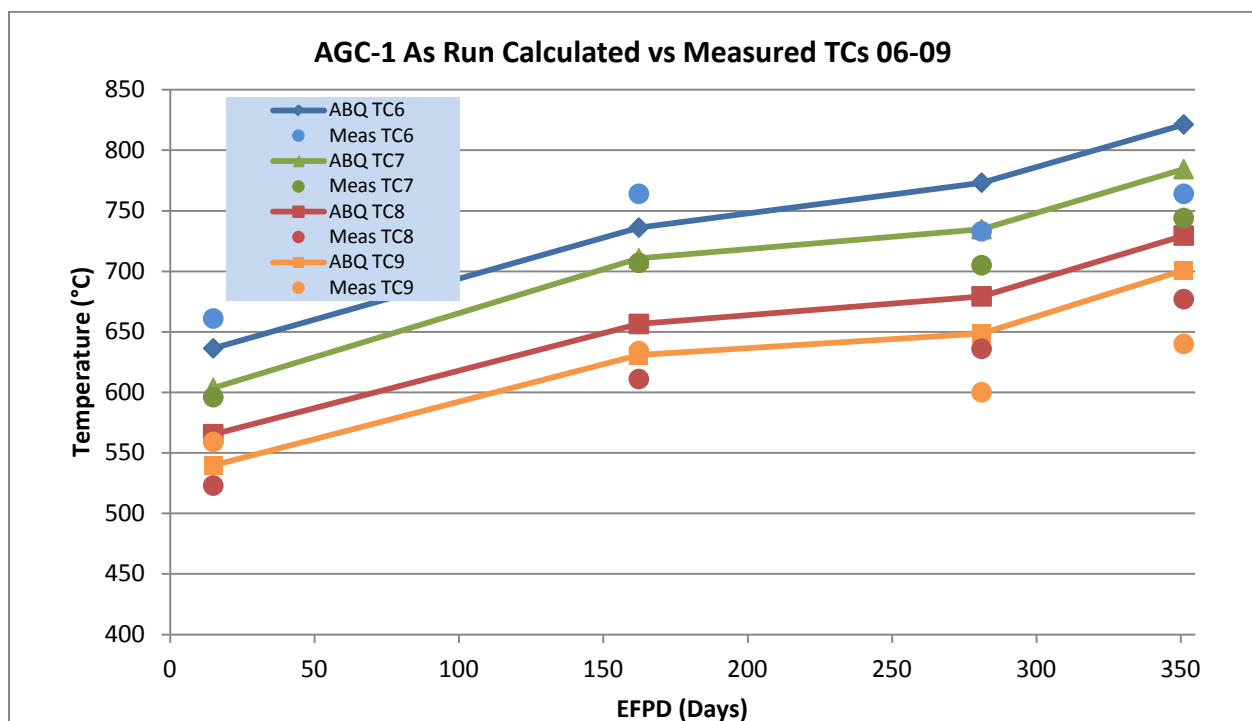


Figure 10. Calculated and measured TC temperatures compared for TCs 6 through 9.

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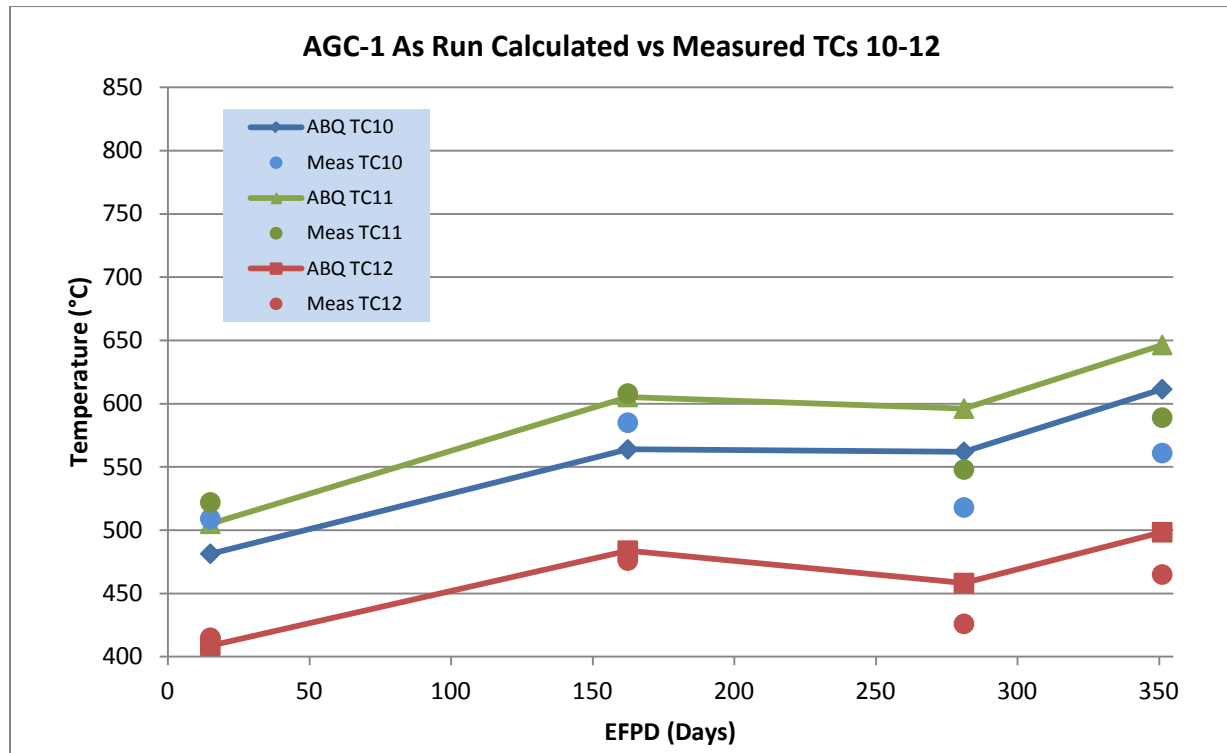


Figure 11. Calculated and measured TC temperatures compared for TCs 10 through 12.

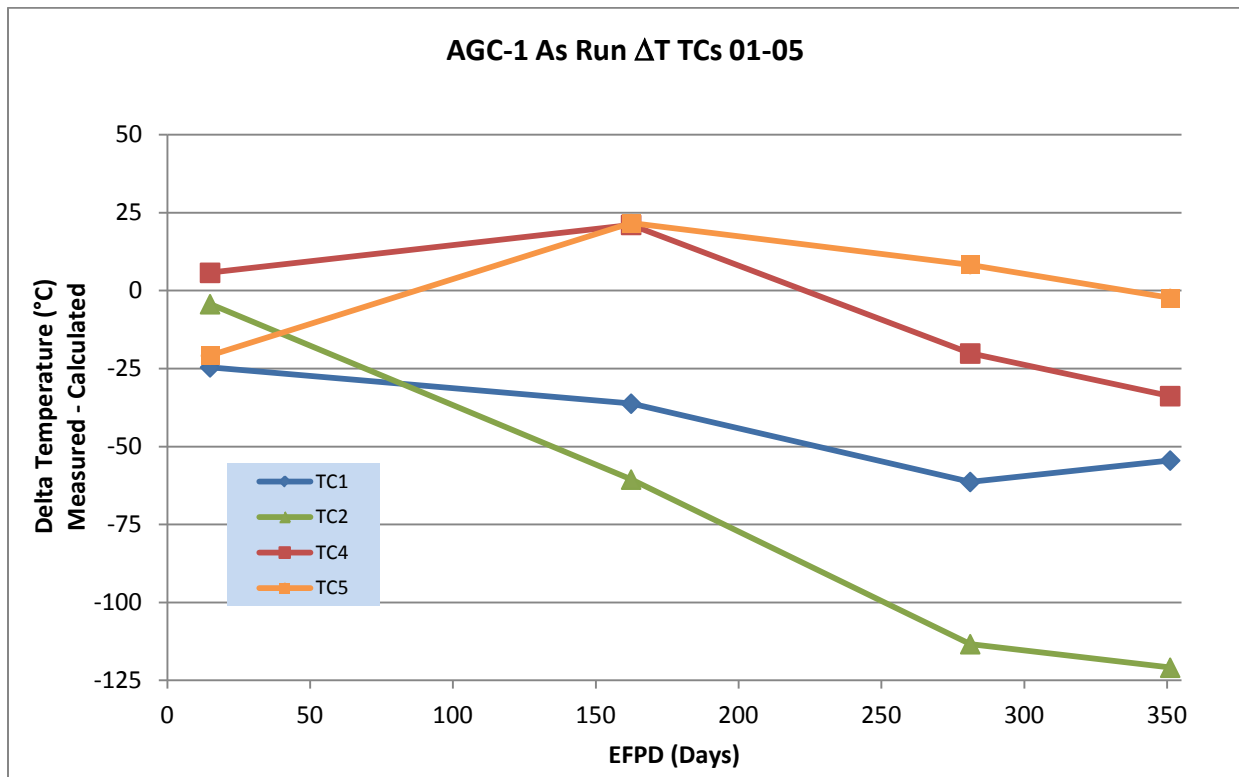


Figure 12. Measured minus calculated temperatures for TCs 1,2,4, and 5.

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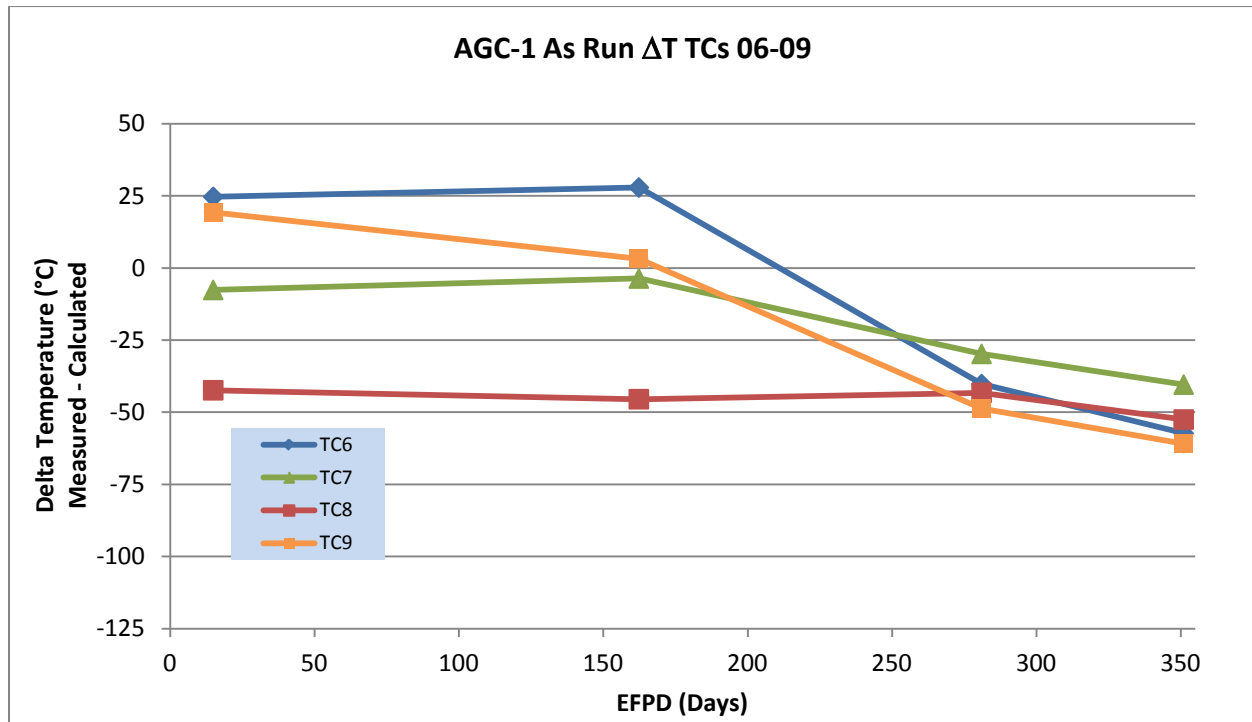


Figure 13. Measured minus calculated temperatures for TCs 6-9.

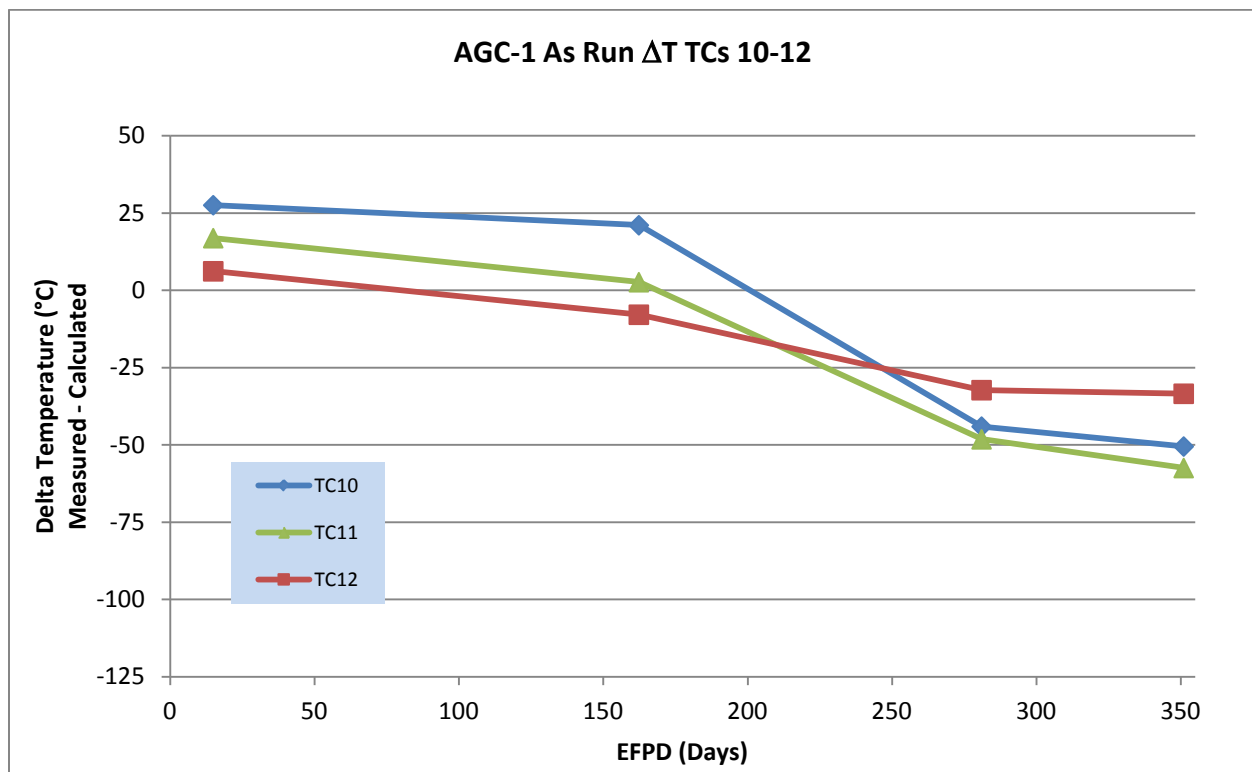


Figure 14. Measured minus calculated temperatures for TCs 10-12.

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REFERENCES

1. James R. Parry, "Neutronics Analysis Of The AGC-1 Experiment Irradiated In The ATR South Flux Trap," ECAR-215, April 28, 2009.
2. Richard G. Ambrosek, "Thermal Projections for AGC-1 With Modified Thermal Shield," ECAR-364, April 28, 2009.

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APPENDIX A—ABAQUS Version 6.9-2 Validation Report on Icestorm

```

ABQ EXE: abq692
COMPUTER: service0_ice_inel_gov
OS: Linux
OS TYPE: 2.6.16.60-0.54.5-smp
t1
=====
ODB: Test-1
dictTest[Test-1].Keys:  ['Grp1']
#####
      NT11-n325
Max error: 1.20% <-----
Max1: 37.3320 Min1: 10.5200 Range: 26.8120
Abq Max2: 37.7813 Abq Min2: 10.6362 Range: 27.1451
      NT11-n281
Max error: 1.48% <-----
Max1: 55.1070 Min1: 13.9970 Range: 41.1100
Abq Max2: 54.7760 Abq Min2: 14.2043 Range: 40.5717
=====

t2
=====
ODB: Test-2
dictTest[Test-2].Keys:  ['Grp2', 'Grp1']
#####
      NT15-n61
Max error: 1.34% <-----
Max1: 37.3320 Min1: 10.5200 Range: 26.8120
Abq Max2: 37.7366 Abq Min2: 10.6609 Range: 27.0756
#####
      NT11-n61
Max error: 1.54% <-----
Max1: 55.1070 Min1: 13.9970 Range: 41.1100
Abq Max2: 54.7444 Abq Min2: 14.2131 Range: 40.5313
=====

t3
=====
ODB: Test-3
dictTest[Test-3].Keys:  ['Grp1']
#####
      NT11-n130
Max error: 1.65% <-----
Max1: 44.5920 Min1: 12.5210 Range: 32.0710
Abq Max2: 44.7825 Abq Min2: 12.7270 Range: 32.0555
      NT11-n59
Max error: 1.85% <-----
Max1: 55.3390 Min1: 14.7770 Range: 40.5620
Abq Max2: 55.0396 Abq Min2: 15.0511 Range: 39.9885
=====

t4
=====
ODB: Test-4
dictTest[Test-4].Keys:  ['Grp1']
#####
      NT11-n281
Error: 0.00% <-----
Ans: 13.7600 Abq: 13.7600
      NT11-n303
Error: 0.00% <-----
Ans: 11.3200 Abq: 11.3200
      NT11-n325
Error: 0.00% <-----
Ans: 4.0000 Abq: 4.0000
      NT11-n314
Error: 0.00% <-----
Ans: 8.2700 Abq: 8.2700

```

```

      NT11-n292
Error: 0.00% <-----
Ans: 13.1500 Abq: 13.1500
=====

t5
=====
ODB: Test-5
dictTest[Test-5].Keys:  ['Grp3', 'Grp2', 'Grp1',
'Grp5', 'Grp4']
#####
      NT13-n62
Error: 0.00% <-----
Ans: 11.3200 Abq: 11.3200
#####
      NT12-n62
Error: 0.00% <-----
Ans: 13.1500 Abq: 13.1500
#####
      NT11-n62
Error: 0.00% <-----
Ans: 13.7600 Abq: 13.7600
#####
      NT15-n62
Error: 0.00% <-----
Ans: 4.0000 Abq: 4.0000
#####
      NT14-n62
Error: 0.00% <-----
Ans: 8.2700 Abq: 8.2700
=====

t6
=====
ODB: Test-6
dictTest[Test-6].Keys:  ['Grp1']
#####
      NT11-n533
Max error: 0.39% <-----
Max1: 80.7640 Min1: 61.8970 Range: 18.8670
Abq Max2: 80.4914 Abq Min2: 61.7364 Range: 18.7551
      NT11-n803
Max error: 0.38% <-----
Max1: 94.5930 Min1: 71.5310 Range: 23.0620
Abq Max2: 94.3007 Abq Min2: 71.2781 Range: 23.0226
=====

t7
=====
ODB: Test-7
dictTest[Test-7].Keys:  ['Grp1']
#####
      HFL-e56
Error: 0.19% <-----
Ans: -0.1700 Abq: -0.1697
=====

t8
=====
ODB: Test-8
dictTest[Test-8].Keys:  ['Grp1']
#####
      HFL-e1121
Error: 1.74% <-----
Ans: 0.1710 Abq: 0.1740
      HFL-e3678
Error: 2.25% <-----
Ans: -0.1620 Abq: -0.1656
=====

```

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```

t9
=====
ODB: Test-9
dictTest[Test-9].Keys:  ['Grp1']
##### 
      NT11-n13
Error: 0.01%  <-----
Ans:      50.0010      Abq:      50.0036
      NT11-n17
Error: 0.00%  <-----
Ans:      55.5500      Abq:      55.5500
      NT11-n328
Error: 0.20%  <-----
Ans:      51.6040      Abq:      51.7074
      NT11-n38
Error: 0.05%  <-----
Ans:      50.0890      Abq:      50.1148
      NT11-n28
Error: 0.11%  <-----
Ans:      50.7010      Abq:      50.7550
      NT11-n218
Error: 0.01%  <-----
Ans:      50.0110      Abq:      50.0176
      NT11-n32
Error: 0.10%  <-----
Ans:      50.3060      Abq:      50.3555
      NT11-n324
Error: 0.20%  <-----
Ans:      52.4260      Abq:      52.5321
      NT11-n4
Error: 0.08%  <-----
Ans:      51.0600      Abq:      51.1006
      NT11-n320

```

```

Error: 0.16%  <-----
Ans:      53.6690      Abq:      53.7552
=====
t10
=====
ODB: Test-10
dictTest[Test-10].Keys:  ['Grp1']
##### 
      NT11-n325
Error: 0.15%  <-----
Ans:      215.7130      Abq:      216.0345
=====
t11
=====
ODB: Test-11
dictTest[Test-11].Keys:  ['Grp1']
##### 
      HFL-e55
Error: 0.02%  <-----
Ans:      -5.5000      Abq:      -5.4989
=====
t12
=====
ODB: Test-12
dictTest[Test-12].Keys:  ['Grp1']
##### 
      NT11-n336
Error: 0.00%  <-----
Ans:      406.6667      Abq:      406.6667
=====

```

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APPENDIX B—Source Code for Program to Obtain Volume Average Temperatures

```

program agc_vat
dimension numlines(1000),vat(1000)
dimension temp(10000),evol(10000)
character*37 junk37
character*1 junk1
character*6 name
character*25 name2,name3
character*54 a1
character*5 a2
character*35 f1,l1
character*25 f2,l2
character*95 b1,c1,d1,e1,g1,h1,i1,j1,k1,m1,n1,junk

a1='leaf = dgo.LeafFromElementSets(elementSets=('PART-1-1.'
a2='', ))'
b1='session.viewports[''Viewport: 1''].odbDisplay.displayGroup.
&replace(leaf=leaf)'
c1='odb = session.odbs[''/home/haw/agc/VATemp/
&agclasrun145a-a1/agclasrun145a-a1m.odb'']'
d1='nf = NumberFormat(numDigits=6, precision=0, format=
&SCIENTIFIC)'
e1='session.fieldReportOptions.setValues(numberFormat=nf)'
f1='session.writeFieldReport(fileName='')'
f2='.degF', append=OFF,'
g1='sortItem='Element Label'', odb=odb, step=0, frame=1,'
h1='outputPosition=ELEMENT_CENTROID, variable=('TEMP'
&, ELEMENT_CENTROID), )'
i1=c1
j1='nf = NumberFormat(numDigits=6, precision=0, format=
&SCIENTIFIC)'
k1='session.fieldReportOptions.setValues(numberFormat=nf)'
l1='session.writeFieldReport(fileName='')'
l2='.evol', append=OFF,'
m1='sortItem='Element Label'', odb=odb, step=0, frame=1,'
n1='outputPosition=WHOLE_ELEMENT, variable=('EVOL',
&WHOLE_ELEMENT), )'

numsets=405
open(unit=33,file='elsets')
open(unit=34,file='agclasrun145a-a1.script1')
open(unit=40,file='agclasrun145a-a1.out')

do 10 i=1,numsets
read(33,'(a37,a6)')junk37,name
junk=a1//trim(name)//trim(a2)
write(34,500)junk
junk=trim(b1)
write(34,500)junk
junk=trim(c1)
write(34,500)junk
junk=trim(d1)
write(34,500)junk
junk=trim(e1)
write(34,500)junk
junk=f1//trim(name)//trim(f2)
write(34,500)junk
junk=trim(g1)
write(34,500)junk
junk=trim(h1)
write(34,500)junk
junk=trim(i1)
write(34,500)junk
junk=trim(j1)
write(34,500)junk
junk=trim(k1)
write(34,500)junk
junk=l1//trim(name)//trim(l2)
write(34,500)junk
junk=trim(m1)
write(34,500)junk
junk=trim(n1)
write(34,500)junk

```

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```

10  continue

    call system('cat top_script agclasrun145a-a1.script1 >
&      abaqus_rpy_script1')
    call system('abq692 viewer script=abaqus_rpy_script1')
    call system('mkdir files')
    call system('rm files/*.degF files/*.evol')
    call system('mv *.degF files/.')
    call system('mv *.evol files/.')

    rewind(33)
    do 20 i=1,numsets
        read(33,'(a37,a6)')junk37,name
        name2='files/'//trim(name)//'.degF'
        name3='files/'//trim(name)//'.evol'
        name2=trim(name2)
        name3=trim(name3)
        open(unit=35,file=name2)
        open(unit=36,file=name3)
        iline=0
12  continue
        read(35,'(a1)',end=19)junk1
        iline=iline+1
        goto 12
19  continue
        numlines(i)=iline

        rewind(35)
        rewind(36)
        sumtop=0.0
        sumbot=0.0

        do 30 j=1,numlines(i)

c ==== reset all values to zero =====
            temp(j)=0.0
            evol(j)=0.0
c =====

            if(j.le.19) then
                read(35,'(a1)')junk1
                read(36,'(a1)')junk1
            endif
            if((j.ge.20) .and. (j.le.numlines(i)-11)) then
                read(35,*)nelem,temp(j-19)
                read(36,*)nelem,evol(j-19)
            endif
            sumtop=sumtop + temp(j-19)*evol(j-19)
            sumbot=sumbot + evol(j-19)
30  continue
        if(i.eq.1)write(40,501)
        vat(i)=sumtop/sumbot
        write(40,502)trim(name),vat(i),((vat(i) - 32)/1.8)
        close(35)
        close(36)
20  continue

500  format(a95)
501  format(1x,' elset',' degrees F',' degrees C',/,
& ' =====')
502  format(1x,a6,2x,f10.2,2x,f10.2)

End

```

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top_script

```
# -*- coding: mbcs -*-
#
# Abaqus/Viewer Version 6.8-2 replay file
# Internal Version: 2008_07_21-07.21.56 87172
# Run by haw on Mon Jan 23 11:47:16 2012
#

# from driverUtils import executeOnCaeGraphicsStartup
# executeOnCaeGraphicsStartup()
# #: Executing "onCaeGraphicsStartup()" in the site directory ...
# #: Executing "onCaeGraphicsStartup()" in the home directory ...
from abaqus import *
from abaqusConstants import *
session.Viewport(name='Viewport: 1', origin=(0.0, 0.0), width=594.39111328125,
    height=404.354461669922)
session.viewports['Viewport: 1'].makeCurrent()
session.viewports['Viewport: 1'].maximize()
from viewerModules import *
from driverUtils import executeOnCaeStartup
executeOnCaeStartup()
o1 = session.openOdb(name='/home/haw/agc/VATemp/agclasrun145a-a1/agclasrun145a-alm.odb')
session.viewports['Viewport: 1'].setValues(displayedObject=o1)
# : Model: /home/haw/agc/VATemp/agclasrun145a-a1/agclasrun145a-alm.odb
# : Number of Assemblies: 1
# : Number of Assembly instances: 0
# : Number of Part instances: 1
# : Number of Meshes: 1
# : Number of Element Sets: 594
# : Number of Node Sets: 23
# : Number of Steps: 1
```

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master reader

```
program agc1_reader
dimension temp(23,405)
character*22 junk

open(unit=11,file='agclasrun145a-a1.out')
open(unit=12,file='agclasrun145a-a2.out')
open(unit=13,file='agclasrun145a-a3.out')
open(unit=14,file='agclasrun145b-b1.out')
open(unit=15,file='agclasrun145b-b2.out')
open(unit=16,file='agclasrun145b-b3.out')
open(unit=17,file='agclasrun146a-a1.out')
open(unit=18,file='agclasrun146a-a2.out')
open(unit=19,file='agclasrun146a-a3.out')
open(unit=20,file='agclasrun146b-b1.out')
open(unit=21,file='agclasrun146b-b2.out')
open(unit=22,file='agclasrun146b-b3.out')
open(unit=23,file='agclasrun147a-a1.out')
open(unit=24,file='agclasrun147a-a2.out')
open(unit=25,file='agclasrun147a-a3.out')
open(unit=26,file='agclasrun147a-a4.out')
open(unit=27,file='agclasrun148a-a1.out')
open(unit=28,file='agclasrun148a-a2.out')
open(unit=29,file='agclasrun148a-a3.out')
open(unit=30,file='agclasrun148a-a4.out')
open(unit=31,file='agclasrun148b-b1.out')
open(unit=32,file='agclasrun148b-b2.out')
open(unit=33,file='agclasrun148b-b3.out')

open(unit=40,file='agc1_master_out')

read(11,'(a22)')junk
read(12,'(a22)')junk
read(13,'(a22)')junk
read(14,'(a22)')junk
read(15,'(a22)')junk
read(16,'(a22)')junk
read(17,'(a22)')junk
read(18,'(a22)')junk
read(19,'(a22)')junk
read(20,'(a22)')junk
read(21,'(a22)')junk
read(22,'(a22)')junk
read(23,'(a22)')junk
read(24,'(a22)')junk
read(25,'(a22)')junk
read(26,'(a22)')junk
read(27,'(a22)')junk
read(28,'(a22)')junk
read(29,'(a22)')junk
read(30,'(a22)')junk
read(31,'(a22)')junk
read(32,'(a22)')junk
read(33,'(a22)')junk
read(11,'(a22)')junk
read(12,'(a22)')junk
read(13,'(a22)')junk
read(14,'(a22)')junk
read(15,'(a22)')junk
read(16,'(a22)')junk
read(17,'(a22)')junk
read(18,'(a22)')junk
read(19,'(a22)')junk
read(20,'(a22)')junk
read(21,'(a22)')junk
read(22,'(a22)')junk
read(23,'(a22)')junk
read(24,'(a22)')junk
read(25,'(a22)')junk
read(26,'(a22)')junk
read(27,'(a22)')junk
read(28,'(a22)')junk
read(29,'(a22)')junk
read(30,'(a22)')junk
read(31,'(a22)')junk
```

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```
read(32, '(a22, f9.2)') junk
read(33, '(a22, f9.2)') junk
```

```
do 100 j=1,405
  read(11, '(a22, f9.2)') junk, temp(1, j)
  read(12, '(a22, f9.2)') junk, temp(2, j)
  read(13, '(a22, f9.2)') junk, temp(3, j)
  read(14, '(a22, f9.2)') junk, temp(4, j)
  read(15, '(a22, f9.2)') junk, temp(5, j)
  read(16, '(a22, f9.2)') junk, temp(6, j)
  read(17, '(a22, f9.2)') junk, temp(7, j)
  read(18, '(a22, f9.2)') junk, temp(8, j)
  read(19, '(a22, f9.2)') junk, temp(9, j)
  read(20, '(a22, f9.2)') junk, temp(10, j)
  read(21, '(a22, f9.2)') junk, temp(11, j)
  read(22, '(a22, f9.2)') junk, temp(12, j)
  read(23, '(a22, f9.2)') junk, temp(13, j)
  read(24, '(a22, f9.2)') junk, temp(14, j)
  read(25, '(a22, f9.2)') junk, temp(15, j)
  read(26, '(a22, f9.2)') junk, temp(16, j)
  read(27, '(a22, f9.2)') junk, temp(17, j)
  read(28, '(a22, f9.2)') junk, temp(18, j)
  read(29, '(a22, f9.2)') junk, temp(19, j)
  read(30, '(a22, f9.2)') junk, temp(20, j)
  read(31, '(a22, f9.2)') junk, temp(21, j)
  read(32, '(a22, f9.2)') junk, temp(22, j)
  read(33, '(a22, f9.2)') junk, temp(23, j)
```

```
100  continue
```

```
do 110 jj=1,405
  write(40, 500) (temp(i, jj), i=1, 23)
```

```
110  continue
```

```
500  format(23(f9.2, 1x))
```

```
end
```

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File Structure on Icestorm

```

service0.1115 ~/agc/agc-1/VATemp => pwd
/home/haw/agc/agc-1/VATemp
service0.1116 ~/agc/agc-1/VATemp => ll
total 440
drwxr-xr-x 26 haw 4096 2012-07-12 10:47 ./
drwxr-xr-x 4 haw 4096 2012-07-12 10:36 ../
drwxr-xr-x 4 haw 4096 2012-08-14 11:12 agclasrun145a-a1/
drwxr-xr-x 3 haw 4096 2012-05-25 12:04 agclasrun145a-a2/
drwxr-xr-x 3 haw 4096 2012-05-25 13:38 agclasrun145a-a3/
drwxr-xr-x 3 haw 4096 2012-05-25 13:48 agclasrun145b-b1/
drwxr-xr-x 3 haw 4096 2012-05-25 14:00 agclasrun145b-b2/
drwxr-xr-x 3 haw 4096 2012-05-25 14:29 agclasrun145b-b3/
drwxr-xr-x 3 haw 4096 2012-05-25 15:33 agclasrun146a-a1/
drwxr-xr-x 3 haw 4096 2012-05-29 10:09 agclasrun146a-a2/
drwxr-xr-x 3 haw 4096 2012-05-29 10:15 agclasrun146a-a3/
drwxr-xr-x 3 haw 4096 2012-05-29 10:22 agclasrun146b-b1/
drwxr-xr-x 3 haw 4096 2012-05-29 10:30 agclasrun146b-b2/
drwxr-xr-x 3 haw 4096 2012-05-29 10:57 agclasrun146b-b3/
drwxr-xr-x 3 haw 28672 2012-07-19 14:16 agclasrun147a-a1/
drwxr-xr-x 3 haw 28672 2012-07-19 14:34 agclasrun147a-a2/
drwxr-xr-x 3 haw 28672 2012-07-19 14:50 agclasrun147a-a3/
drwxr-xr-x 3 haw 28672 2012-07-19 14:59 agclasrun147a-a4/
drwxr-xr-x 3 haw 28672 2012-07-19 15:39 agclasrun148a-a1/
drwxr-xr-x 3 haw 28672 2012-07-20 07:49 agclasrun148a-a2/
drwxr-xr-x 3 haw 28672 2012-07-20 07:59 agclasrun148a-a3/
drwxr-xr-x 3 haw 28672 2012-07-20 13:34 agclasrun148a-a4/
drwxr-xr-x 3 haw 28672 2012-07-20 12:32 agclasrun148b-b1/
drwxr-xr-x 3 haw 28672 2012-07-20 13:17 agclasrun148b-b2/
drwxr-xr-x 3 haw 28672 2012-07-20 13:29 agclasrun148b-b3/
-rwxr--r-- 1 haw 5706 2012-05-25 11:51 copier*
-rw-r--r-- 1 haw 17408 2012-03-05 15:35 elsets
drwxr-xr-x 2 haw 4096 2012-07-20 13:32 master/
service0.1117 ~/agc/agc-1/VATemp => ll agclasrun145a-a1/
total 83784
drwxr-xr-x 4 haw 4096 2012-08-14 11:12 ./
drwxr-xr-x 26 haw 4096 2012-07-12 10:47 ../
-rw-r--r-- 1 haw 4004 2012-08-14 11:22 abaqus.rpy
-rw-r--r-- 1 haw 1353 2012-05-21 10:44 abaqus.rpy.1
-rw-r--r-- 1 haw 1353 2012-05-21 11:00 abaqus.rpy.2
-rw-r--r-- 1 haw 11309 2012-05-21 16:18 abaqus.rpy.3
-rw-r--r-- 1 haw 3613 2012-07-02 11:50 abaqus.rpy.4
-rw-r--r-- 1 haw 545506 2012-05-21 10:47 abaqus_rpy_script1
-rwxr-x-- 1 haw 83418532 2012-05-21 10:34 agclasrun145a-a1m.odb*
-rw-r--r-- 1 haw 13024 2012-05-21 11:00 agclasrun145a-a1.out
-rw-r--r-- 1 haw 544320 2012-05-21 10:47 agclasrun145a-a1.script1
-rw-r--r-- 1 haw 3993 2012-05-21 10:46 agc_vat.f
-rwxr--r-- 1 haw 66 2012-05-16 16:26 agc_vat.mak*
-rwxr-xr-x 1 haw 812084 2012-05-21 10:47 agc_vat.x*
-rw-r--r-- 1 haw 17408 2012-05-21 10:15 elsets
drwxr-xr-x 2 haw 28672 2012-07-02 15:04 files/
drwxr-xr-x 2 haw 4096 2012-07-11 16:54 rgarerun/
-rw-r--r-- 1 haw 1186 2012-05-21 10:37 top_script
service0.1118 ~/agc/agc-1/VATemp => ll master
total 1248
drwxr-xr-x 2 haw 4096 2012-07-20 13:32 ./
drwxr-xr-x 26 haw 4096 2012-07-12 10:47 ../
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun145a-a1.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun145a-a2.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun145a-a3.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun145b-b1.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun145b-b2.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun145b-b3.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun146a-a1.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun146a-a2.out

```

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```

-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun146a-a3.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun146b-b1.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun146b-b2.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun146b-b3.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun147a-a1.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun147a-a2.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun147a-a3.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun147a-a4.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun148a-a1.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun148a-a2.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun148a-a3.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun148a-a4.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun148b-b1.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun148b-b2.out
-rw-r--r-- 1 haw 13024 2012-07-20 13:31 agclasrun148b-b3.out
-rw-r--r-- 1 haw 93150 2012-07-20 13:31 agcl_master_out
-rw-r--r-- 1 haw 3708 2012-05-29 16:38 agcl_master_reader.f
-rwxr--r-- 1 haw 110 2012-05-29 16:21 agcl_master_reader.mak*
-rwxr-xr-x 1 haw 766007 2012-05-29 16:38 agcl_master_reader.x*
-rwxr--r-- 1 haw 713 2012-05-29 15:37 copier_out*
-rwxr--r-- 1 haw 3084 2012-05-29 15:42 differ*
-rw-r--r-- 1 haw 1357 2012-05-29 15:50 list
  
```

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APPENDIX C—References for Graphite Shrinkage

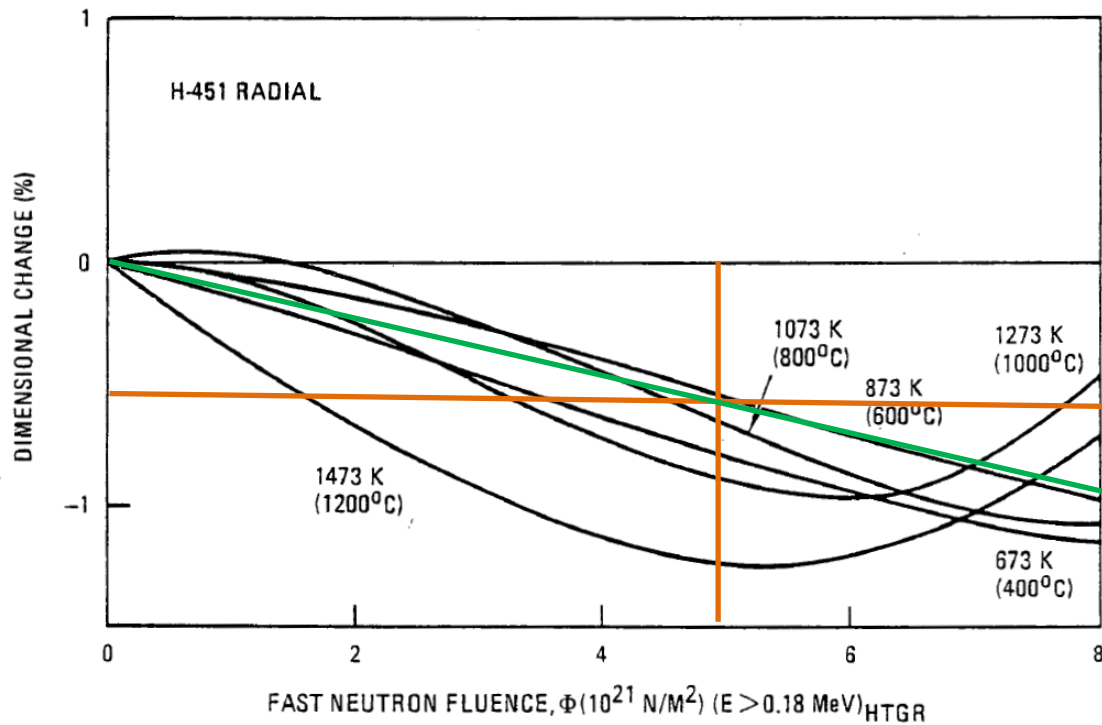


Fig. 4.6-2. Design curves for dimensional change of H-451 graphite, radial orientation, as a function of irradiation conditions

Note: Units should be 10^{25} n/m². A shrinkage of 0.15% is calculated from a dimensional change of -0.6% for a fluence of 4.86 (4.0 DPA).

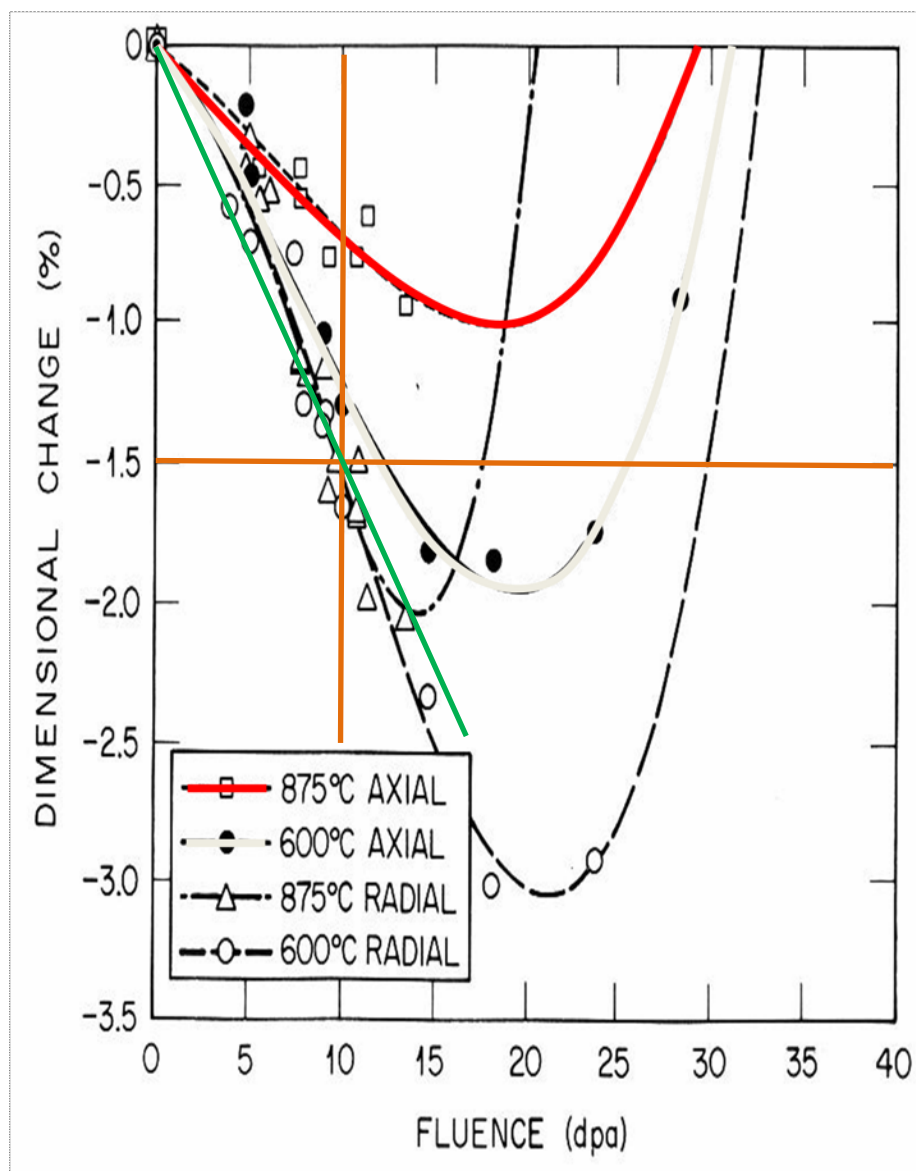
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Neutron irradiation-induced dimensional change curves for GraphNOL N3M graphite irradiated at 600 or 875°C (Burchell and Eatherly 1991) Note: Fluence = 10 is 8.23 DPA, showing a dimensional change of 1.23%, or 0.15% per DPA.