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Data Compilation for AGC-2 Matrix-only Compact Lot A3-P43

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Data Compilation for AGC-2 Matrix-only Compact Lot A3-P43

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This document is a compilation of fabrication and characterization data for the compact lot A3-P43, which was produced for possible insertion into the second ATR Graphite Creep irradiation test capsule (AGC-2). The compacts were produced by Oak Ridge National Laboratory (ORNL) for the Advanced Gas Reactor Fuel Development and Qualification (AGR) program. This compact lot was fabricated using a graphite/resin blend formulated by INL as a candidate matrix precursor for scale-up of overcoating and compacting processes. The matrix precursor powder for compact lot A3-P43 was a jet milled blend of 64 wt% natural graphite (Asbury 3482), 16 wt% synthetic graphite (Graftech GTI-D), and 20 wt% of a standard novolac resin (Plenco 14043).

The “Matrix Compacts for AGC-2 Irradiation” Specification (INL SPC-1285, Rev. 1) provides the requirements necessary for acceptance of the compacts. Sections 2.03 and 2.04 of SPC-1285 provide the property requirements for the heat-treated compacts. There are requirements on the length, diameter, and matrix density. Section 2.02.01.01 further requests impurity analysis on representative samples from the final compact lot, but there are no specified acceptance criteria. The impurity information will be evaluated by INL as part of a final decision on whether to insert the compacts into the AGC-2 experiment. The procedures for characterizing and qualifying the compacts are outlined in ORNL product inspection plan AGR-CHAR-PIP-16. The measurement of compact length, diameter, and matrix density was performed according to data acquisition method AGR-CHAR-DAM-39. The data report forms generated by this procedure document the product acceptance for the property requirements listed in sections 2.03 and 2.04 of SPC-1285. All compacts selected for irradiation conformed to the specified requirements for length, diameter, and density.

In addition to the characterization data, this report also contains other records relevant to the product acceptance. A history of the material flow and sample naming is included and the compacting process is summarized. In addition to results of the impurity analysis on representative samples from the final compact lot, impurity analysis results are also provided for samples of the graphite, resin, and the graphite/resin blend. A Certificate of Conformance to SPC-1285, Rev. 1 is attached in Appendix B.

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1 Material identification record for A3-P43

Table 1-1 lists the materials used to make the A3-P43 compacts. The graphite/resin blend was shipped from Babcock and Wilcox (B&W) to ORNL on October 4, 2010. Three completed compacts were shipped to INL on October 28, 2010. Three compacts were also shipped to Shiva Technologies for impurity analysis on October 29, 2010. Fourteen compacts were retained at ORNL. Table 1-2 lists the disposition of each compact. Table 1-3 is a copy of data report form DRF-39B, which lists the specific assignment of final compact ID for each fabricated compact.

Table 1-1: Material identification record for A3-P43 compacts

Sample ID	Parent material	Notes
Blend D	Asbury 3482 natural graphite lot# 7602 Graftech GTI-D synthetic graphite CAS# 7782-42-5 Plenco 14043 Batch# 930951	Parent material information provided by INL
A3-P43-#	Blend D	Ten cylinders, A3-P43-1 through A3-P43-10, pressed from Blend D and carbonized
A3-P43-#-A and A3-P43-#-B	A3-P43-#	Two compacts machined from each of ten carbonized cylinders, A3-P43-1 through A3-P43-10
A3-P43-Z##	A3-P43-#-A and A3-P43-#-B	Twenty heat-treated compacts randomized and relabeled, A3-P43-Z01 through A3-P43-Z20 (see DRF-39B for specific assignment record)

Table 1-2: Disposition of A3-P43 compacts

Sent to INL	Sent to Shiva	Retained at ORNL		
A3-P43-Z03	A3-P43-Z07	A3-P43-Z01	A3-P43-Z10	A3-P43-Z17
A3-P43-Z12	A3-P43-Z08	A3-P43-Z02	A3-P43-Z11	A3-P43-Z18
A3-P43-Z06 (spare)	A3-P43-Z15	A3-P43-Z04	A3-P43-Z13	A3-P43-Z19
		A3-P43-Z05	A3-P43-Z14	A3-P43-Z20
		A3-P43-Z09	A3-P43-Z16	

Table 1-3. Record of assignment of Z-number to fabricated compacts (DRF-39B)

Data Report Form DRF-39B: Compact Tracking

Procedure:	AGR-CHAR-DAM-39 Rev. 0
Operator:	John Hunn
Compact lot ID:	A3-P43
Compact Lot description:	Matrix-only compacts from Plenco 14043
Filename:	\\mc-agr\AGR\CompactDimensions\A3-P43_DRF39R0.xls

Compact Z Number	Compact Fab Number
Z01	10-A
Z02	8-A
Z03	4-B
Z04	7-B
Z05	4-A

Compact Z Number	Compact Fab Number
Z06	5-B
Z07	3-B
Z08	6-A
Z09	2-B
Z10	9-A

Compact Z Number	Compact Fab Number
Z11	1-B
Z12	3-A
Z13	6-B
Z14	9-B
Z15	5-A

Compact Z Number	Compact Fab Number
Z16	2-A
Z17	1-A
Z18	10-B
Z19	8-B
Z20	7-A

Comments

John Hunn
Operator

10-27-10
Date

2 Inspection of Length, Diameter, and Matrix Density

At the end of this section is the data report form DRF-39A associated with the compact lot A3-P43. This data report form summarizes the acceptance testing performed according to the product inspection plan AGR-CHAR-PIP-16. The information in this form covers all the property specifications listed in sections 2.03 and 2.04 of SPC-1285. All compacts met the specified criteria for diameter and matrix density. Seven compacts did not meet the specified criteria for length. These compacts were not used. All compacts selected for irradiation or impurity analysis met all dimensional and density specifications. Note that the specification only requires compacts used for irradiation meet these requirements, so the final determination of this inspection is that the product (compacts used for irradiation) conforms to the specified requirements for length, diameter, and density.

Table 2-1 summarizes the critical properties of the compacts selected for possible insertion in the AGC-2 irradiation experiment. Table 2-2 is a copy of data report form DRF-39A.

Table 2-1. Summary of properties of compact shipped for irradiation

Compact ID	Length (mm)	Diameter (mm)	Density (g/cm^3)
A3-P43-Z03	6.315	12.74	1.759
A3-P43-Z12	6.337	12.73	1.796
A3-P43-Z06 (spare)	6.350	12.74	1.753
Specification	$6.299 \le x \le 6.350$	$12.700 \le x \le 12.751$	1.75 ± 0.13

Table 2-2. Record of compact acceptance test for dimensions and density (DRF-39A)

Data Report Form DRF-39A: Compact Diameter, Length, and Density

Procedure:	AGR-CHAR-DAM-39 Rev. 0
Operator:	John Hunn
Compact lot ID:	A3-P43
Compact Lot description:	Matrix-only compacts from Pienco 14043
Filename:	\\mc-agr\AGR\CompactDimensions\A3-P43_DRF39R0.xls

Vertical height gauge calibration due date:	3/22/11
Digital caliper calibration due date:	5/11/11
Gauge blocks calibration due date:	11/7/12
Analytical balance calibration due date:	9/13/11

Acceptance criteria for compact length:	≥6.299 and ≤6.350 mm
Acceptance criteria for compact diameter:	≥12.700 and ≤12.751 mm
Acceptance criteria for compact mass:	For information only
Acceptance criteria for compact density:	1.75±0.13 g/cm^3

Compact ID Number	Mass (g)	Length (mm)	Diameter (mm)			Volume (cm^3)	Density (g/cm^3)	Accept?
			0°	90°	Average			(pass or fail)
Z01	1.5043	6.374	12.72	12.72	12.72	0.8100	1.8572	fail
Z02	1.4972	6.372	12.73	12.73	12.73	0.8110	1.8461	fail
Z03	1.4163	6.315	12.74	12.74	12.74	0.8050	1.7594	pass
Z04	1.3601	6.330	12.71	12.71	12.71	0.8031	1.6935	pass
Z05	1.4917	6.363	12.74	12.74	12.74	0.8111	1.8390	fail
Z06	1.4190	6.350	12.74	12.74	12.74	0.8095	1.7530	pass
Z07	1.3907	6.330	12.72	12.72	12.72	0.8044	1.7289	pass
Z08	1.4853	6.344	12.74	12.74	12.74	0.8087	1.8366	pass
Z09	1.3853	6.314	12.72	12.72	12.72	0.8024	1.7265	pass
Z10	1.4195	6.334	12.72	12.72	12.72	0.8049	1.7636	pass
Z11	1.3843	6.336	12.72	12.72	12.72	0.8052	1.7193	pass
Z12	1.4473	6.337	12.73	12.72	12.73	0.8059	1.7958	pass
Z13	1.4229	6.325	12.73	12.73	12.73	0.8050	1.7675	pass
Z14	1.4476	6.323	12.72	12.72	12.72	0.8035	1.8016	pass
Z15	1.4819	6.344	12.74	12.74	12.74	0.8087	1.8324	pass
Z16	1.4338	6.333	12.72	12.72	12.72	0.8048	1.7816	pass
Z17	1.4633	6.352	12.73	12.73	12.73	0.8085	1.8100	fail
Z18	1.4603	6.360	12.72	12.73	12.73	0.8088	1.8054	fail
Z19	1.3749	6.358	12.72	12.72	12.72	0.8080	1.7017	fail
Z20	1.4725	6.353	12.74	12.74	12.74	0.8099	1.8182	fail

Comments

Seven compacts failed length specification (too long). These will not be used.
All but one compact had side fissures and end damage.
Z19 had the best surface appearance, but was too long.
Z03 and Z12 had minor side fissures and end damage and will be shipped for irradiation.
Z06 had minor side fissures and end damage, it will be shipped as a spare.

John Hunn — Operator — Date: 10-27-10

John Hunn — QC Supervisor — Date: 10-28-10

QA Reviewer — Date: 10/28/10

3 Inspection of Compact Surface Appearance

All but 1 compact had obvious surface fissures on the sides (Figure 3-1) and surface damage on one or both ends (Figure 3-2). The one compact that did not have obvious side fissures and end damage (A3-P43-Z19) was 0.008 mm too long and was not selected for irradiation. Two of the compacts that exhibited only minor surface fissures (Figure 3-3) and end damage (Figure 3-4 and Figure 3-5) were selected for irradiation (see Table 1-2). A third compact was selected as a spare, based on the fact that it also only exhibited minor side fissures and end damage.

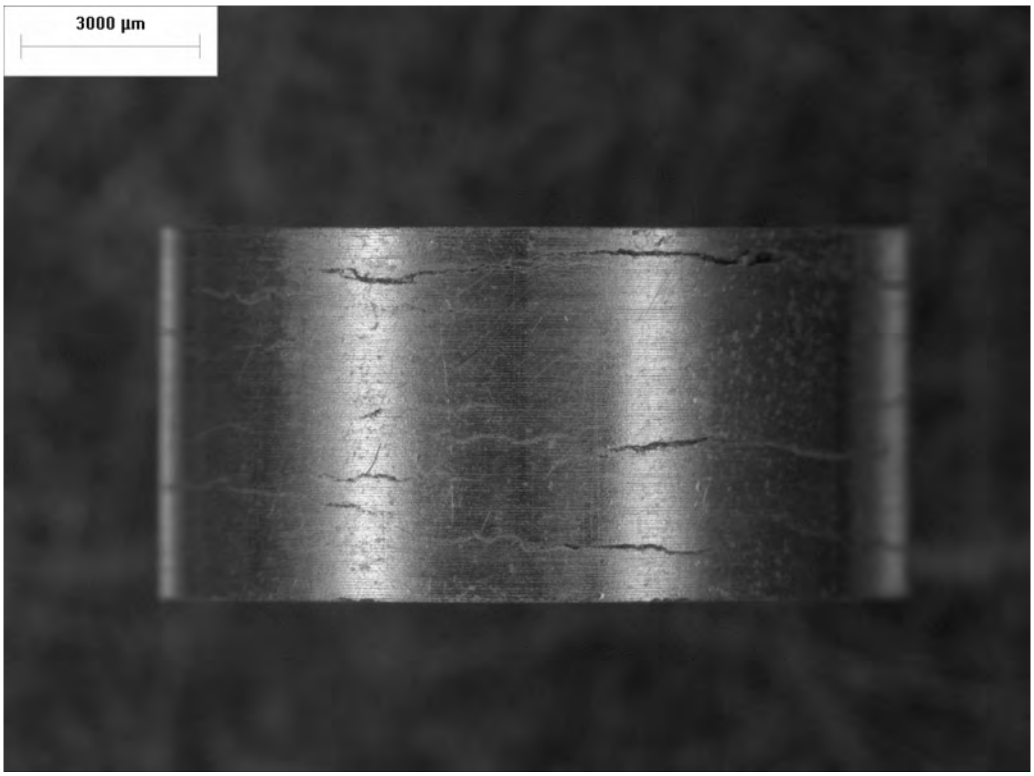

Figure 3-1. Fissures were observed to a varying degree on the sides of most compacts. An example of side fissures on compact A3-H08-Z04 from a similar compact lot is shown.

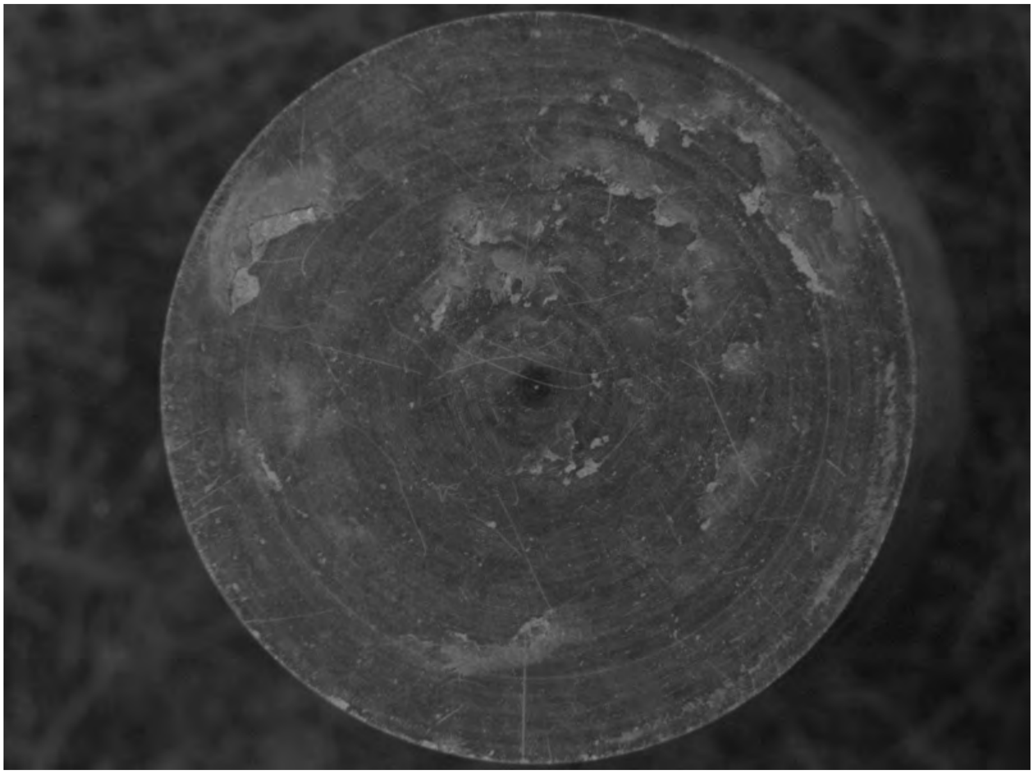

Figure 3-2. End faces of many compacts showed damage that looked like flakes of material were delaminating and sometimes breaking away. Compact A3-H08-Z04 is shown.

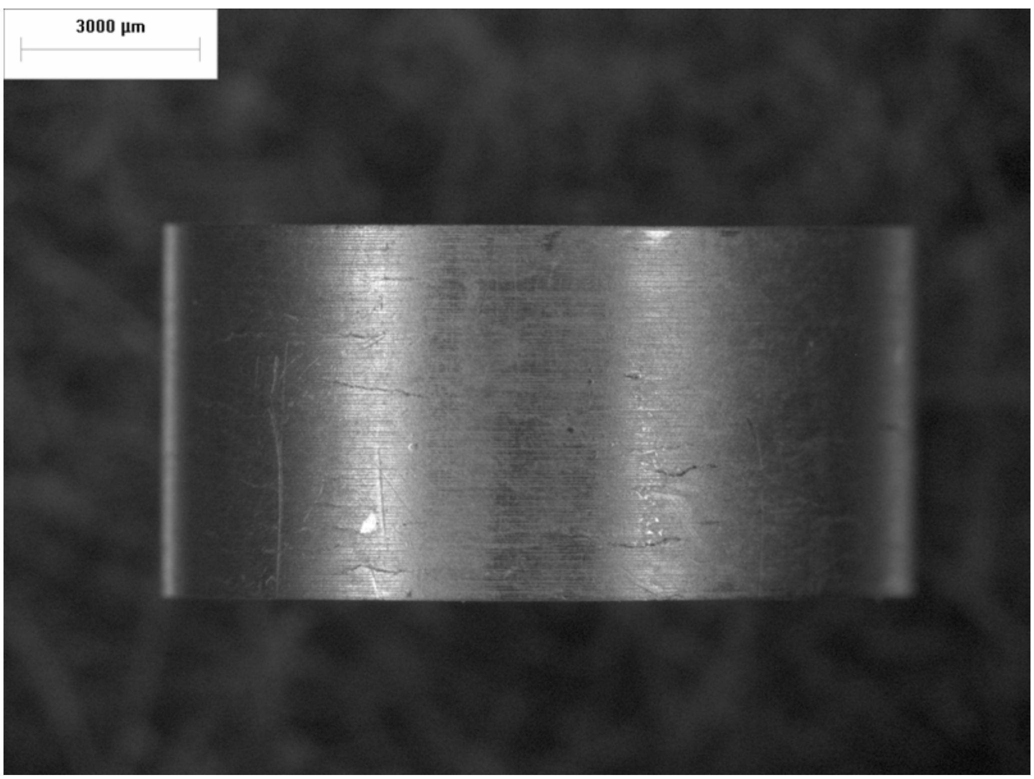

Figure 3-3. Minor side fissure on compact A3-P43-Z03 (selected for irradiation).

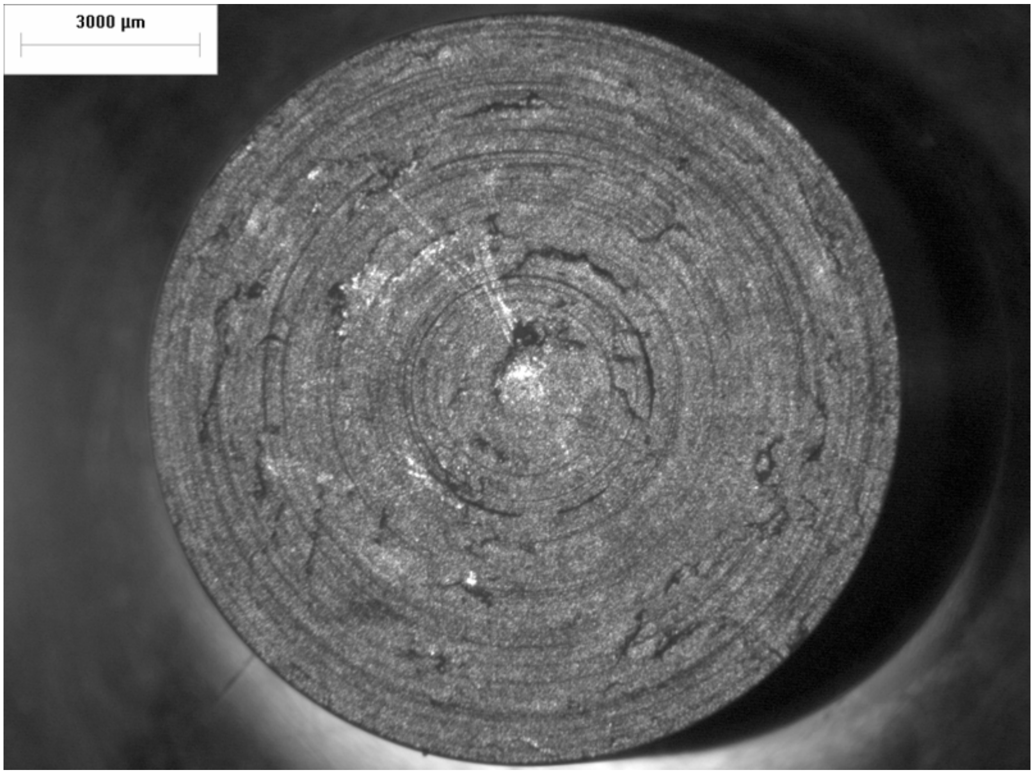

Figure 3-4. Minor damage on one end of compact A3-P43-Z03 (selected for irradiation).

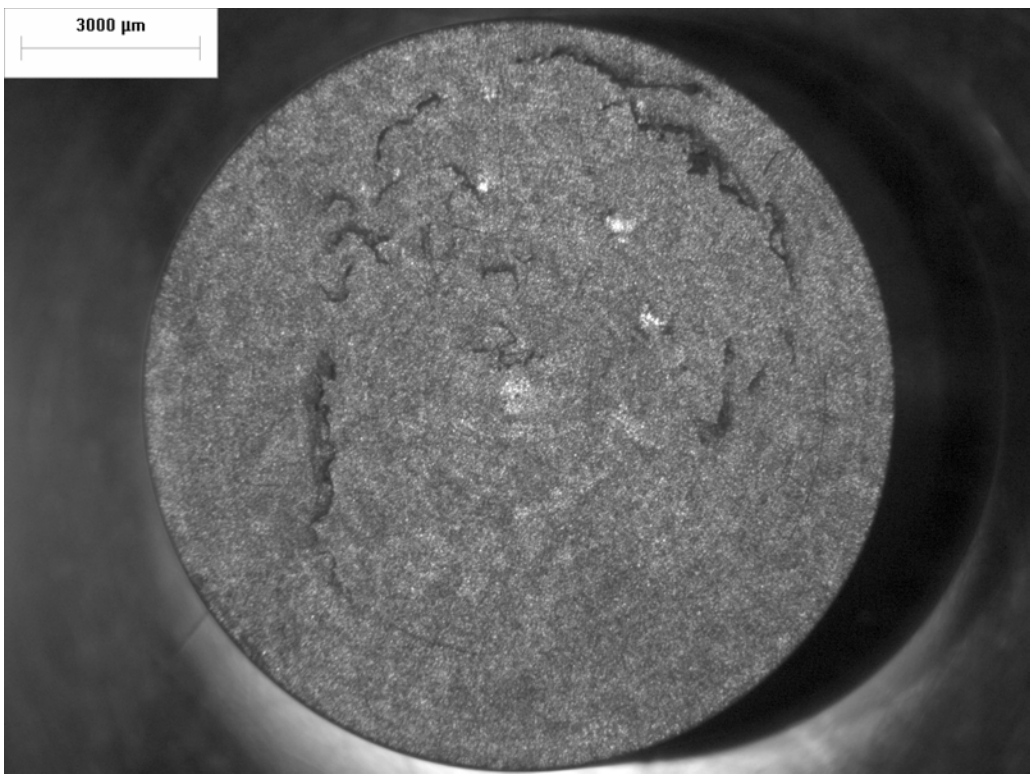

Figure 3-5. Minor damage on other end of compact A3-P43-Z03 (selected for irradiation).

4 Compacting process conditions

Initial matrix-only compacting tests were performed using parameters suggested by INL, which were selected based on manufacturer provided resin properties and previous experiments with overcoated material. These test compacts exhibited problems including delamination or fracture during ejection from the die and development of fissures during carbonization. The higher fraction of resin in the matrix-only compacts compared to compacts made from overcoated particles may have been a contributing factor to the difficulties encountered. To reduce the observed cracking, additional development was carried out before the final matrix-only compacts were fabricated. As part of this development, several compacts were made at various pressing conditions to determine the most effective fabrication methods. A summary of the final fabrication procedure is outlined below. This procedure was able to produce compacted cylinders with minimal visible flaws in the as-compacted (green) state. However, fissures still developed during carbonization.

AGC-2 matrix-only compacts needed to be nominally 12.7 mm in diameter, 6.35 mm in length, and 1.75 g/cm^3 in density. Normally, a custom die would be made to produce compacts with the required dimensions. However, a limited time was available for fabrication of these compacts in order to have them available for inclusion in the AGC-2 irradiation test. The required fabrication schedule made it infeasible to obtain a new compacting die with a diameter that would yield the desired final compact diameter after heat-treatment. As an alternative approach, a slightly over-sized (15.24 mm diameter) die was used to produce 10 cylinders from each matrix blend that were then machined into the final 20 compacts. The die was single-acting, that is, the top punch moved and the bottom punch was fixed. To obtain two compacts from each carbonized cylinder, a minimum length of at least 25.4 mm long was desired to allow for gripping of the cylinder and machining loss. However, the compacting die, which had ~75 mm of available length for loading, was not tall enough to hold the amount of as-received matrix precursor powder required to produce a compacted cylinder at least 25.4 mm long. The jet milled powder had a low bulk density, so a pre-compacting method for the as-received powder was developed to allow the required amount of feed material to fit in the available die. Another die (25.4 mm diameter) was used to produce ~1 g/cm^3 slugs, which were re-granulated into a coarse powder that would work with the 15.24 mm diameter compacting die. These low density slugs were made by filling the 25.4 mm diameter die at room temperature with the as-received matrix precursor blend and pressing to 8 kN. The slugs were then broken into granules and passed through a U.S. Standard #20 (850 μm nominal opening) sieve to remove any large chunks.

Table 4-1 provides a summary of the critical steps in the compacting schedule. All AGC-2 matrix-only compacts were made using standard operating procedure AGR-COMP-SOP-10, "Production of AGC Irradiation Specimens" and the following pressing schedule. Using the pre-compacting method described above, charges were prepared and weighed out while the compacting die, top punch, and bottom punch were heated simultaneously to 130±1°C. The compact charge weight was calculated to produce a compact of the required length and density, based on empirical data on weight loss and shrinkage. During heating, the inner diameter and contact surfaces of the top and bottom punches were lightly sprayed with McLube 860 mold release agent and allowed to dry. The charge was poured into the compacting die within an approximately 30 second long period. The top punch was put in place and the matrix precursor material was allowed to warm up in the die for an additional 20-30 seconds before the programmed compacting sequence was initiated on the Promess press. The press ram was advanced at 1 mm/sec, taking approximately 20 seconds to reach the target position. This target position was chosen to produce a compact of the desired length. At 1 mm short of the target position, there was a 1 second delay. This delay provided additional relaxation time for the material and reduced the peak force applied during compacting. After the 1 second delay, the press continued to move to the target position. Once at the target position, the press held position for 60 seconds. After the hold, the press retracted and an ejection block was set in place to allow the lower punch and cylinder to be ejected from the bottom of the die.

Table 4-1. Compacting schedule summary

Step	Action	Timing	Comments
1	Load die	~30 sec to load	
2	Delay	~30 sec	Allow matrix precursor material to heat up
3	Initiate program		
4	Move to position	~20 sec	Pressing at 1 mm/sec
5	Delay	1 sec	Hold position 1 mm short of target position
6	Move to position	1 sec	Continue to target position at 1mm/sec
7	Delay	60 sec	Hold position
8	Move to position	N/A	Retract for ejection
9	Move to position	N/A	Eject part at 3 mm/sec

The compacted cylinders were carbonized per procedure AGR-COMP-SOP-04, “Carbonizing Compacts” by heating to 950°C at a rate of 1°C/min in flowing helium, followed by a 1 hour hold. The carbonized cylinders were machined according to drawing AGR-COMP-DWG-03, “AGC Compact Drawing” (see appendix A). Cylinders were first turned down to the target diameter. Prior to cutting two compacts of the target length from each cylinder, a thin layer of material was removed from the end to square the cylinder. The two machined compacts were identified by adding “A” or “B” to the fabrication ID relative to their location within the original compact (A being closest to the top of the die). Most of the B compacts came from near the middle of the cylinder. However, two of the compacted cylinders (A3-P43-7 and A3-P43-8) fractured during machining. For these cylinders, the B compact was taken from closer to the bottom of the cylinder. After machining, the compacts were heat-treated per procedure AGR-COMP-SOP-05, “Heat-treating Compacts” by heating to 1800°C under vacuum at a rate of 20°C/min, followed by a 1 hour hold. The main purpose of the heat-treatment process was to reduce impurity content in the compacts. Compacts were heat-treated after machining to reduce the potential for contamination after the heat-treatment step.

Based on previous experience with AGR matrix materials, most dimensional changes in the pressed cylinders were expected to occur during carbonization. However, compacts can also undergo dimensional changes during heat-treatment. These changes are usually a consistent minor shrinkage and can be compensated for by using empirical data to oversize the compacts. During initial testing, it was determined that the dimensional change induced by the heat-treatment of the A3-P43 matrix material was inconsistent. Some test compacts shrank, while others grew in length. For this reason, compacts were machined to a length close to the middle of the specified final length for the heat-treated compacts. This provided the most flexibility and allowed for re-machining of compacts that were too long. Upon inspection of the heat-treated compacts, there were enough compacts with an acceptable length, so re-machining was not necessary.

Table 4-2 provides dimensional analysis for the cylinders before and after carbonization. Table 4-3 provides dimensional analysis for the machined compacts before and after heat-treatment. Table 4-2 also lists the compaction force required to press each green compact. Average density was determined from the measured weight and dimensions assuming a cylindrical geometry.

Because of the presence of fissures in the cylinders and compacts, it is difficult to draw conclusions from the analysis of the data in Table 4-2 and Table 4-3. These fissures were visible in most of the final heat-treated compacts and are discussed in section 3. These fissures can add to the length of the compact and produce an error in the calculated density.

Fractional weight loss after carbonization was consistent in all the cylinders that were measured. Fractional change in length after carbonization was less consistent due to the presence of fissures in the cylinders. Table 4-3 shows that many of the machined compacts were longer after heat-treatment. This was also most likely due to the formation or expansion of these fissures. There was also a slight weight loss after heat-treatment. The calculated density of the compacts taken from closer to the top of the cylinder was higher than those taken from lower down because the compacting force was greater closer to the moving punch.

Table 4-2. Analysis of cylinders before and after carbonization

		Green				Carbonized				Fractional change from green to carbonized			
Fabrication ID	Compaction Force (Mpa)	Length (mm)	Dia (mm)	Mass (g)	Density (g/cm³)	Length (mm)	Dia (mm)	Mass (g)	Density (g/cm³)	Length	Dia	Mass	Density
A3-P43-1	25.4	25.60	15.24	8.3975	1.798	24.95	15.06	7.7432	1.742	0.975	0.988	0.922	0.969
A3-P43-2	26.5	25.98	15.23	8.4087	1.777	25.19	15.06	7.7460	1.726	0.970	0.989	0.921	0.972
A3-P43-3	27.6	25.91	15.23	8.4076	1.781	25.10	15.06	7.7463	1.733	0.969	0.989	0.921	0.973
A3-P43-4	30.5	25.45	15.22	8.4082	1.816	24.81	15.06	7.7420	1.752	0.975	0.989	0.921	0.965
A3-P43-5	29.0	25.56	15.22	8.4022	1.807	24.89	15.04	7.7369	1.750	0.974	0.988	0.921	0.968
A3-P43-6	36.5	25.37	15.21	8.3789	1.818	24.75	15.04	7.7107	1.754	0.976	0.989	0.920	0.965
A3-P43-7	23.3	25.93	15.30	8.4135	1.765	25.14	15.02	7.7438	1.738	0.970	0.982	0.920	0.985
A3-P43-8	29.1	25.55	15.27	8.4035	1.796	24.83	15.03	7.7320	1.755	0.972	0.984	0.920	0.977
A3-P43-9	31.6	25.40	15.18	8.4118	1.830	24.74	15.04	7.7512	1.764	0.974	0.991	0.921	0.964
A3-P43-10	30.1	25.37	15.22	8.3836	1.816	24.66	14.86	7.7242	1.806	0.972	0.976	0.921	0.994

Table 4-3: Analysis of machined compacts before and after heat-treatment

		Carbonized				Heat Treated				Fractional change from carbonized to heat treated			
Fabrication ID	Characterization ID	Length (mm)	Dia (mm)	Mass (g)	Density (g/cm³)	Length (mm)	Dia (mm)	Mass (g)	Density (g/cm³)	Length	Dia	Mass	Density
A3-P43-1-A	A3-P43-Z17	6.34	12.73	1.4706	1.8225	6.352	12.73	1.4633	1.8100	1.002	1.000	0.995	0.993
A3-P43-1-B	A3-P43-Z11	6.34	12.73	1.3917	1.7247	6.336	12.72	1.3843	1.7193	0.999	0.999	0.995	0.997
A3-P43-2-A	A3-P43-Z16	6.31	12.72	1.4400	1.7958	6.333	12.72	1.4338	1.7816	1.004	1.000	0.996	0.992
A3-P43-2-B	A3-P43-Z09	6.31	12.72	1.3916	1.7355	6.314	12.72	1.3853	1.7265	1.001	1.000	0.995	0.995
A3-P43-3-A	A3-P43-Z12	6.31	12.71	1.4528	1.8147	6.337	12.73	1.4473	1.7944	1.004	1.002	0.996	0.989
A3-P43-3-B	A3-P43-Z07	6.32	12.71	1.3966	1.7417	6.330	12.72	1.3907	1.7289	1.002	1.001	0.996	0.993
A3-P43-4-A	A3-P43-Z05	6.32	12.72	1.4973	1.8644	6.363	12.74	1.4917	1.8390	1.007	1.002	0.996	0.986
A3-P43-4-B	A3-P43-Z03	6.30	12.72	1.4222	1.7765	6.315	12.74	1.4163	1.7594	1.002	1.002	0.996	0.990
A3-P43-5-A	A3-P43-Z15	6.31	12.73	1.4874	1.8520	6.344	12.74	1.4819	1.8324	1.005	1.001	0.996	0.989
A3-P43-5-B	A3-P43-Z06	6.33	12.73	1.4247	1.7684	6.350	12.74	1.4190	1.7530	1.003	1.001	0.996	0.991
A3-P43-6-A	A3-P43-Z08	6.31	12.72	1.4905	1.8588	6.344	12.74	1.4853	1.8366	1.005	1.002	0.997	0.988
A3-P43-6-B	A3-P43-Z13	6.30	12.72	1.4288	1.7847	6.325	12.73	1.4229	1.7675	1.004	1.001	0.996	0.990
A3-P43-7-A	A3-P43-Z20	6.32	12.72	1.4779	1.8402	6.353	12.74	1.4725	1.8182	1.005	1.002	0.996	0.988
A3-P43-7-B	A3-P43-Z04	6.34	12.70	1.3671	1.7022	6.330	12.71	1.3601	1.6935	0.998	1.001	0.995	0.995
A3-P43-8-A	A3-P43-Z02	6.34	12.72	1.5028	1.8653	6.372	12.73	1.4972	1.8461	1.005	1.001	0.996	0.990
A3-P43-8-B	A3-P43-Z19	6.36	12.72	1.3817	1.7096	6.358	12.72	1.3749	1.7017	1.000	1.000	0.995	0.995
A3-P43-9-A	A3-P43-Z10	6.31	12.72	1.4991	1.8696	6.334	12.72	1.4195	1.7636	1.004	1.000	0.947	0.943
A3-P43-9-B	A3-P43-Z14	6.32	12.73	1.4565	1.8107	6.323	12.72	1.4476	1.8016	1.000	0.999	0.994	0.995
A3-P43-10-A	A3-P43-Z01	6.35	12.72	1.5106	1.8720	6.374	12.72	1.5043	1.8572	1.004	1.000	0.996	0.992
A3-P43-10-B	A3-P43-Z18	6.35	12.72	1.4678	1.8190	6.360	12.72	1.4603	1.8068	1.002	1.000	0.995	0.993

5 Impurity analysis of matrix, resin, and graphite

Samples of the natural and synthetic graphite, resin, and matrix precursor blend D were sent to Shiva Technologies for impurity analysis. The matrix precursor powder for compact lot A3-P43 was a jet milled blend of 64 wt% natural graphite (Asbury 3482), 16 wt% synthetic graphite (Graftech GTI-D), and 20 wt% of a standard novolac resin (Plenco 14043). The resin and matrix precursor blend were carbonized prior to shipment to Shiva. The carbonization process was used to remove volatiles that would interfere with the impurity analysis. Approximately 5 grams of resin and graphite/resin blend were loaded into separate quartz trays and then placed into a tube furnace. The samples were heated to 950°C at a rate of 5°C/min and held at 950°C for 1 hour. The furnace power was cut and the samples cooled to room temperature. The samples were then loaded into glass vials and shipped to SHIVA for full scan glow discharge mass spectrometry (GDMS) analysis, along with samples of the natural and synthetic graphite.

Table 5-1 is a compilation of the impurity analysis results. Impurities that could not be detected above the analysis threshold value are reported as less than values (<) and appear in gray. Values marked as less than or equal to (=<) indicate that a measurable value of the element was obtained, but that this element may have come from the Shiva sample preparation. Prior to GDMS analysis, Shiva poured the powder samples into a Teflon mold with a binder material. The binder was mostly indium, but may also have contained other elements, as indicated in the analysis report by the “=<” symbol. The resin showed very high values for F, but these were marked as semiquantitative (~) and probably came from the Teflon mold. The natural graphite was very high in Si and also high in Mg, Al, S, and Fe. The synthetic graphite was high in Cu. The impurities in the graphite carried over to the jet milled blend. The resin had high levels of Al, Si, S, and Ca that appeared to also carry over into the jet milled blend.

Copies of the Shiva Technologies certified impurity analysis data sheets for the natural and synthetic graphite are provided in Table 5-2 and Table 5-3. A copy of the certified impurity analysis data sheet for the Plenco resin is provided in Table 5-4. A copy of the certified impurity analysis data sheet for the graphite/resin blend made from these materials (INL Blend D) is provided in Table 5-5.

Samples of the final heat treated compacts were also sent to Shiva for analysis. These results are presented in section. As discussed in that section 6, heat-treatment of the compacts removed some of the impurities present in the graphite/resin blend.

Table 5-1. Summary of feedstock impurities

Element	Concentration (ppm wt)			
	Asbury 3482	**GTI-D**	**Plenco 14043**	**INL Blend D**
Li	< 0.01	< 0.01	0.61	< 0.01
Be	< 0.01	< 0.01	< 0.01	< 0.01
B	0.24	0.77	0.1	0.56
C	Matrix	Matrix	Matrix	Matrix
N	-	-	-	-
O	-	-	-	-
F	~ 20	~ 10	~ 360	~ 10
Na	1.5	11	29	1.9
Mg	80	1.2	23	79
Al	29	0.9	130	37
Si	710	2.7	330	670
P	0.82	< 0.1	2	1.4
S	25	10	460	39
Cl	2.5	7.8	4.6	7.4
K	0.2	< 0.1	3.6	< 0.1
Ca	8.2	3.2	580	51
Sc	< 0.05	< 0.05	< 0.05	< 0.05
Ti	2.3	2.2	5	2.2
V	0.45	9.9	0.07	1.4
Cr	< 0.5	< 0.5	< 0.5	1.8
Mn	0.55	< 0.05	0.2	0.71
Fe	38	1.1	10	40
Co	< 0.05	< 0.05	< 0.05	0.17
Ni	0.25	0.25	0.4	0.95
Cu	2.5	120	5.1	64
Zn	0.4	< 0.1	=< 1.3	< 0.1
Ga	< 0.1	< 0.1	< 0.1	< 0.1
Ge	< 0.1	< 0.1	< 0.1	< 0.1
As	< 0.1	< 0.1	< 0.1	< 0.1
Se	< 0.1	< 0.1	< 0.1	< 0.1
Br	0.41	< 0.1	0.25	1.7
Rb	< 0.05	< 0.05	< 0.05	< 0.05
Sr	0.08	< 0.05	0.33	0.06
Y	0.2	< 0.05	< 0.05	0.09
Zr	0.6	0.14	< 0.05	1.9
Nb	< 0.1	< 0.1	< 0.1	< 0.1
Mo	< 0.05	0.09	0.05	0.29
Ru	< 0.1	< 0.1	< 0.1	< 0.1
Rh	< 0.1	< 0.1	< 0.1	< 0.1
Pd	< 0.1	< 0.1	< 0.1	< 0.1
Ag	< 0.1	< 0.1	< 0.1	< 0.1
Cd	< 0.1	< 0.1	< 0.1	< 0.1
In	Binder	Binder	Binder	Binder

Table 5-1. Summary of feedstock impurities (continued)

Element	Concentration (ppm wt)			
	Asbury 3482	GTI-D	Plenco 14043	INL Blend D
Sn	< 0.5	< 0.5	< 0.5	< 0.5
Sb	< 0.5	< 0.5	< 0.5	< 0.5
Te	< 0.1	< 0.1	< 0.1	< 0.1
I	< 20	=< 80	=< 280	< 20
Cs	< 0.1	< 0.1	< 0.1	< 0.1
Ba	0.8	< 0.1	< 0.1	< 0.1
La	< 0.5	=< 2	=< 11	< 0.5
Ce	< 0.5	< 0.5	< 0.5	< 0.5
Pr	< 0.05	< 0.05	=< 1.5	< 0.05
Nd	< 0.05	< 0.05	< 0.05	< 0.05
Sm	< 0.05	< 0.05	< 0.05	< 0.05
Eu	< 0.05	< 0.05	< 0.05	< 0.05
Gd	< 0.05	< 0.05	< 0.05	< 0.05
Tb	< 0.05	< 0.05	< 0.05	< 0.05
Dy	< 0.05	< 0.05	< 0.05	< 0.05
Ho	< 0.05	< 0.05	< 0.05	< 0.05
Er	< 0.05	< 0.05	< 0.05	< 0.05
Tm	< 0.05	< 0.05	< 0.05	< 0.05
Yb	< 0.05	< 0.05	< 0.05	< 0.05
Lu	< 0.05	< 0.05	< 0.05	< 0.05
Hf	< 0.05	< 0.05	< 0.05	< 0.05
Ta	< 5	< 5	< 5	< 5
W	0.15	< 0.05	0.07	0.21
Re	< 0.05	< 0.05	< 0.05	< 0.05
Os	< 0.05	< 0.05	< 0.05	< 0.05
Ir	< 0.05	< 0.05	< 0.05	< 0.05
Pt	< 0.05	< 0.05	< 0.05	< 0.05
Au	< 0.1	< 0.1	< 0.1	< 0.1
Hg	< 0.5	< 0.5	< 0.5	< 0.5
Tl	< 0.1	< 0.1	< 0.1	< 0.1
Pb	< 0.5	< 0.5	< 0.5	< 0.5
Bi	< 0.1	< 0.1	< 0.1	< 0.1
Th	< 0.05	< 0.05	< 0.05	< 0.05
U	< 0.05	< 0.05	< 0.05	< 0.05

Table 5-2. Impurity analysis report for Asbury 3482 natural graphite lot# 7602

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Customer: **UT-Battelle Oak Ridge**
1 Bethel Valley Rd, Oak Ridge, TN 37823-6063 USA
P.O.# **4000100480**
Date: 6-Nov-10
Job # S0ABV776
Customer ID: **C**
Asbury 3482 NFG
Sample ID: S101101057

Element	Concentration [ppm wt]	Element	Concentration [ppm wt]
Li	< 0.01	Pd	< 0.1
Be	< 0.01	Ag	< 0.1
B	0.24	Cd	< 0.1
C	Matrix	In	Binder
N	-	Sn	< 0.5
O	-	Sb	< 0.5
F	~ 20	Te	< 0.1
Na	1.5	I	< 20
Mg	80	Cs	< 0.1
Al	29	Ba	0.8
Si	710	La	< 0.5
P	0.82	Ce	< 0.5
S	25	Pr	< 0.05
Cl	2.5	Nd	< 0.05
K	0.2	Sm	< 0.05
Ca	8.2	Eu	< 0.05
Sc	< 0.05	Gd	< 0.05
Ti	2.3	Tb	< 0.05
V	0.45	Dy	< 0.05
Cr	< 0.5	Ho	< 0.05
Mn	0.55	Er	< 0.05
Fe	38	Tm	< 0.05
Co	< 0.05	Yb	< 0.05
Ni	0.25	Lu	< 0.05
Cu	2.5	Hf	< 0.05
Zn	0.4	Ta	< 5
Ga	< 0.1	W	0.15
Ge	< 0.1	Re	< 0.05
As	< 0.1	Os	< 0.05
Se	< 0.1	Ir	< 0.05
Br	0.41	Pt	< 0.05
Rb	< 0.05	Au	< 0.1
Sr	0.08	Hg	< 0.5
Y	0.2	Tl	< 0.1
Zr	0.6	Pb	< 0.5
Nb	< 0.1	Bi	< 0.1
Mo	< 0.05	Th	< 0.05
Ru	< 0.1	U	< 0.05
Rh	< 0.1		

~ Semiquantitative Values

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Table 5-3. Impurity analysis report for Graftech GTI_D synthetic graphite #7782-42-5

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Customer: **UT-Battelle Oak Ridge** *P.O.#* **4000100480**
1 Bethel Valley Rd, Oak Ridge, TN 37823-6063 USA
Date: 6-Nov-10 *Job #* S0ABV776
Customer ID: **C** *Sample ID:* S101101058
GTI-D-SG

Element	Concentration [ppm wt]	Element	Concentration [ppm wt]
Li	< 0.01	Pd	< 0.1
Be	< 0.01	Ag	< 0.1
B	0.77	Cd	< 0.1
C	Matrix	In	Binder
N	-	Sn	< 0.5
O	-	Sb	< 0.5
F	~ 10	Te	< 0.1
Na	11	I	=< 80
Mg	1.2	Cs	< 0.1
Al	0.9	Ba	< 0.1
Si	2.7	La	=< 2
P	< 0.1	Ce	< 0.5
S	10	Pr	< 0.05
Cl	7.8	Nd	< 0.05
K	< 0.1	Sm	< 0.05
Ca	3.2	Eu	< 0.05
Sc	< 0.05	Gd	< 0.05
Ti	2.2	Tb	< 0.05
V	9.9	Dy	< 0.05
Cr	< 0.5	Ho	< 0.05
Mn	< 0.05	Er	< 0.05
Fe	1.1	Tm	< 0.05
Co	< 0.05	Yb	< 0.05
Ni	0.25	Lu	< 0.05
Cu	120	Hf	< 0.05
Zn	< 0.1	Ta	< 5
Ga	< 0.1	W	< 0.05
Ge	< 0.1	Re	< 0.05
As	< 0.1	Os	< 0.05
Se	< 0.1	Ir	< 0.05
Br	< 0.1	Pt	< 0.05
Rb	< 0.05	Au	< 0.1
Sr	< 0.05	Hg	< 0.5
Y	< 0.05	Tl	< 0.1
Zr	0.14	Pb	< 0.5
Nb	< 0.1	Bi	< 0.1
Mo	0.09	Th	< 0.05
Ru	< 0.1	U	< 0.05
Rh	< 0.1		

~ Semiquantitative Values

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Table 5-4. Impurity analysis report for Plenco 14043 batch# 930951

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1 Bethel Valley Rd, Oak Ridge, TN 37823-6063 USA
P.O.# **4000100480**
Date: 6-Nov-10
Job # S0ABV776
Customer ID: **C**
Plenco 14043
Sample ID: S101101059

Element	Concentration [ppm wt]	Element	Concentration [ppm wt]
Li	0.61	Pd	< 0.1
Be	< 0.01	Ag	< 0.1
B	0.1	Cd	< 0.1
C	Matrix	In	Binder
N	-	Sn	< 0.5
O	-	Sb	< 0.5
F	~ 360	Te	< 0.1
Na	29	I	=< 280
Mg	23	Cs	< 0.1
Al	130	Ba	< 0.1
Si	330	La	=< 11
P	2	Ce	< 0.5
S	460	Pr	=< 1.5
Cl	4.6	Nd	< 0.05
K	3.6	Sm	< 0.05
Ca	580	Eu	< 0.05
Sc	< 0.05	Gd	< 0.05
Ti	5	Tb	< 0.05
V	0.07	Dy	< 0.05
Cr	< 0.5	Ho	< 0.05
Mn	0.2	Er	< 0.05
Fe	10	Tm	< 0.05
Co	< 0.05	Yb	< 0.05
Ni	0.4	Lu	< 0.05
Cu	5.1	Hf	< 0.05
Zn	=< 1.3	Ta	< 5
Ga	< 0.1	W	0.07
Ge	< 0.1	Re	< 0.05
As	< 0.1	Os	< 0.05
Se	< 0.1	Ir	< 0.05
Br	0.25	Pt	< 0.05
Rb	< 0.05	Au	< 0.1
Sr	0.33	Hg	< 0.5
Y	< 0.05	Tl	< 0.1
Zr	< 0.05	Pb	< 0.5
Nb	< 0.1	Bi	< 0.1
Mo	0.05	Th	< 0.05
Ru	< 0.1	U	< 0.05
Rh	< 0.1		

~ Semiquantitative Values

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Table 5-5. Impurity analysis report for INL graphite/resin Blend D

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Customer: **UT-Battelle Oak Ridge**
1 Bethel Valley Rd, Oak Ridge, TN 37823-6063 USA
P.O.# **4000100480**
Date: 7-Nov-10
Job # S0ABV776
Customer ID: **C**
INL Blend D
Sample ID: S101101063

Element	Concentration [ppm wt]	Element	Concentration [ppm wt]
Li	< 0.01	Pd	< 0.1
Be	< 0.01	Ag	< 0.1
B	0.56	Cd	< 0.1
C	Matrix	In	Binder
N	-	Sn	< 0.5
O	-	Sb	< 0.5
F	~ 10	Te	< 0.1
Na	1.9	I	< 20
Mg	79	Cs	< 0.1
Al	37	Ba	< 0.1
Si	670	La	< 0.5
P	1.4	Ce	< 0.5
S	39	Pr	< 0.05
Cl	7.4	Nd	< 0.05
K	< 0.1	Sm	< 0.05
Ca	51	Eu	< 0.05
Sc	< 0.05	Gd	< 0.05
Ti	2.2	Tb	< 0.05
V	1.4	Dy	< 0.05
Cr	1.8	Ho	< 0.05
Mn	0.71	Er	< 0.05
Fe	40	Tm	< 0.05
Co	0.17	Yb	< 0.05
Ni	0.95	Lu	< 0.05
Cu	64	Hf	< 0.05
Zn	< 0.1	Ta	< 5
Ga	< 0.1	W	0.21
Ge	< 0.1	Re	< 0.05
As	< 0.1	Os	< 0.05
Se	< 0.1	Ir	< 0.05
Br	1.7	Pt	< 0.05
Rb	< 0.05	Au	< 0.1
Sr	0.06	Hg	< 0.5
Y	0.09	Tl	< 0.1
Zr	1.9	Pb	< 0.5
Nb	< 0.1	Bi	< 0.1
Mo	0.29	Th	< 0.05
Ru	< 0.1	U	< 0.05
Rh	< 0.1		

~ Semiquantitative Values

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6 Inspection of heat-treated compact impurities

Three heat-treated compacts were sent to Shiva Technologies for impurity analysis (see Table 1-2). Although not required by the specification, these compacts also met the requirements for diameter, length, and density placed on the compacts used for irradiation. Where possible within this limitation, compacts were selected that were machined from the same pressed cylinders as the compacts selected for irradiation.

Table 6-1 is a compilation of the impurity analysis results. The impurities in the feedstock materials were discussed in section 5. For comparison, Table 6-1 includes the impurity analysis for the matrix blend D used to make the A3-P43 compacts. Impurities that could not be detected above the analysis threshold value are reported as less than values (<) and appear in gray. There is no indication that the compacting process significantly increased any of the impurity levels in the heat-treated matrix-only compacts above what was already in the matrix precursor. Some impurities were significantly reduced by the heat-treatment (e.g., Na, Cl, Cr, Fe, Ni, and Cu). Mg was reduced, but not as significantly. Other impurities present at moderate levels in the graphite/resin blend seemed to be somewhat reduced but were still preset at moderate levels (e.g., Al, S, and Ca). The very high Si content from the natural graphite was reduced by about 15-30% in the heat-treated compacts, but was still very high.

Copies of the Shiva Technologies certified impurity analysis data sheets for the three heat-treated compacts are provided in Table 6-2, Table 6-3, and Table 6-4.

Table 6-1. Summary of heat-treated compact impurities

Element	Concentration (ppm wt)			
	A3-P43-Z07	A3-P43-Z08	A3-P43-Z15	INL Blend D
Li	< 0.01	< 0.01	< 0.01	< 0.01
Be	< 0.01	< 0.01	< 0.01	< 0.01
B	0.11	0.11	0.12	0.56
C	Matrix	Matrix	Matrix	Matrix
N	-	-	-	-
O	-	-	-	-
F	< 1	< 1	< 1	~ 10
Na	< 0.05	< 0.05	< 0.05	1.9
Mg	19	28	10	79
Al	28	30	23	37
Si	560	570	480	670
P	0.95	1.3	1.1	1.4
S	27	50	35	39
Cl	0.43	0.31	0.16	7.4
K	< 0.1	< 0.1	< 0.1	< 0.1
Ca	21	44	25	51
Sc	< 0.05	< 0.05	< 0.05	< 0.05
Ti	0.88	1.9	1.1	2.2
V	0.79	1.6	0.88	1.4
Cr	< 0.5	< 0.5	< 0.5	1.8
Mn	< 0.05	< 0.05	< 0.05	0.71
Fe	0.17	0.22	0.08	40
Co	< 0.05	< 0.05	< 0.05	0.17
Ni	< 0.1	< 0.1	< 0.1	0.95
Cu	< 0.1	< 0.1	< 0.1	64
Zn	< 0.1	< 0.1	< 0.1	< 0.1
Ga	< 0.1	< 0.1	< 0.1	< 0.1
Ge	< 0.1	< 0.1	< 0.1	< 0.1
As	< 0.1	< 0.1	< 0.1	< 0.1
Se	< 0.1	< 0.1	< 0.1	< 0.1
Br	< 0.1	< 0.1	< 0.1	1.7
Rb	< 0.05	< 0.05	< 0.05	< 0.05
Sr	< 0.05	< 0.05	< 0.05	0.06
Y	< 0.05	0.09	< 0.05	0.09
Zr	1.1	1.3	0.89	1.9
Nb	< 0.1	< 0.1	< 0.1	< 0.1
Mo	0.13	0.17	0.17	0.29
Ru	< 0.1	< 0.1	< 0.1	< 0.1
Rh	< 0.1	< 0.1	< 0.1	< 0.1
Pd	< 0.1	< 0.1	< 0.1	< 0.1
Ag	< 0.1	< 0.1	< 0.1	< 0.1
Cd	< 0.1	< 0.1	< 0.1	< 0.1
In	< 0.1	< 0.1	< 0.1	Binder

Table 6-1. Summary of heat-treated compact impurities (continued)

Element	Concentration (ppm wt)			
	A3-P43-Z07	A3-P43-Z08	A3-P43-Z15	INL Blend D
Sn	< 0.5	< 0.5	< 0.5	< 0.5
Sb	< 0.5	< 0.5	< 0.5	< 0.5
Te	< 0.1	< 0.1	< 0.1	< 0.1
I	< 0.1	< 0.1	< 0.1	< 20
Cs	< 0.1	< 0.1	< 0.1	< 0.1
Ba	< 0.1	0.19	0.17	< 0.1
La	< 0.5	< 0.5	< 0.5	< 0.5
Ce	< 0.05	< 0.05	< 0.05	< 0.5
Pr	< 0.05	< 0.05	< 0.05	< 0.05
Nd	< 0.05	< 0.05	< 0.05	< 0.05
Sm	< 0.05	< 0.05	< 0.05	< 0.05
Eu	< 0.05	< 0.05	< 0.05	< 0.05
Gd	< 0.05	< 0.05	< 0.05	< 0.05
Tb	< 0.05	< 0.05	< 0.05	< 0.05
Dy	< 0.05	< 0.05	< 0.05	< 0.05
Ho	< 0.05	< 0.05	< 0.05	< 0.05
Er	< 0.05	< 0.05	< 0.05	< 0.05
Tm	< 0.05	< 0.05	< 0.05	< 0.05
Yb	< 0.05	< 0.05	< 0.05	< 0.05
Lu	< 0.05	< 0.05	< 0.05	< 0.05
Hf	< 0.05	< 0.05	< 0.05	< 0.05
Ta	< 5	< 5	< 5	< 5
W	0.13	0.45	0.35	0.21
Re	< 0.05	< 0.05	< 0.05	< 0.05
Os	< 0.05	< 0.05	< 0.05	< 0.05
Ir	< 0.05	< 0.05	< 0.05	< 0.05
Pt	< 0.05	< 0.05	< 0.05	< 0.05
Au	< 0.1	< 0.1	< 0.1	< 0.1
Hg	< 0.5	< 0.5	< 0.5	< 0.5
Tl	< 0.1	< 0.1	< 0.1	< 0.1
Pb	< 0.5	< 0.5	< 0.5	< 0.5
Bi	< 0.1	< 0.1	< 0.1	< 0.1
Th	< 0.05	< 0.05	< 0.05	< 0.05
U	< 0.05	< 0.05	< 0.05	< 0.05

Table 6-2. Impurity analysis report for heat-treated compact A3-P43-Z07

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GDMS
ANALYTICAL REPORT

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Customer: **UT-Battelle Oak Ridge**
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P.O.# **4000100480**
Date: 8-Nov-10
Job # S0ABV776
Customer ID: **C**
A3-P43-Z07
Sample ID: S101101072

Element	Concentration [ppm wt]	Element	Concentration [ppm wt]
Li	< 0.01	Pd	< 0.1
Be	< 0.01	Ag	< 0.1
B	0.11	Cd	< 0.1
C	Matrix	In	< 0.1
N	-	Sn	< 0.5
O	-	Sb	< 0.5
F	< 1	Te	< 0.1
Na	< 0.05	I	< 0.1
Mg	19	Cs	< 0.1
Al	28	Ba	< 0.1
Si	560	La	< 0.5
P	0.95	Ce	< 0.05
S	27	Pr	< 0.05
Cl	0.43	Nd	< 0.05
K	< 0.1	Sm	< 0.05
Ca	21	Eu	< 0.05
Sc	< 0.05	Gd	< 0.05
Ti	0.88	Tb	< 0.05
V	0.79	Dy	< 0.05
Cr	< 0.5	Ho	< 0.05
Mn	< 0.05	Er	< 0.05
Fe	0.17	Tm	< 0.05
Co	< 0.05	Yb	< 0.05
Ni	< 0.1	Lu	< 0.05
Cu	< 0.1	Hf	< 0.05
Zn	< 0.1	Ta	< 5
Ga	< 0.1	W	0.13
Ge	< 0.1	Re	< 0.05
As	< 0.1	Os	< 0.05
Se	< 0.1	Ir	< 0.05
Br	< 0.1	Pt	< 0.05
Rb	< 0.05	Au	< 0.1
Sr	< 0.05	Hg	< 0.5
Y	< 0.05	Tl	< 0.1
Zr	1.1	Pb	< 0.5
Nb	< 0.1	Bi	< 0.1
Mo	0.13	Th	< 0.05
Ru	< 0.1	U	< 0.05
Rh	< 0.1		

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Table 6-3. Impurity analysis report for heat-treated compact A3-P43-Z08

EAG Evans Analytical Group

GDMS
ANALYTICAL REPORT

SHIVA Technologies
An Operating Unit of Evans Analytical Group LLC
6707 Brooklawn Parkway
Syracuse, New York 13211

Telephone (315) 431-9900
Fax: (315) 431-9800
Email info.ny@eaglabs.com
www.eaglabs.com

Customer: **UT-Battelle Oak Ridge**
1 Bethel Valley Rd, Oak Ridge, TN 37823-6063 USA
P.O.# **4000100480**

Date: 8-Nov-10
Job # S0ABV776

Customer ID: **C**
A3-P43-Z08
Sample ID: S101101073

Element	Concentration [ppm wt]	Element	Concentration [ppm wt]
Li	< 0.01	Pd	< 0.1
Be	< 0.01	Ag	< 0.1
B	0.11	Cd	< 0.1
C	Matrix	In	< 0.1
N	-	Sn	< 0.5
O	-	Sb	< 0.5
F	< 1	Te	< 0.1
Na	< 0.05	I	< 0.1
Mg	28	Cs	< 0.1
Al	30	Ba	0.19
Si	570	La	< 0.5
P	1.3	Ce	< 0.05
S	50	Pr	< 0.05
Cl	0.31	Nd	< 0.05
K	< 0.1	Sm	< 0.05
Ca	44	Eu	< 0.05
Sc	< 0.05	Gd	< 0.05
Ti	1.9	Tb	< 0.05
V	1.6	Dy	< 0.05
Cr	< 0.5	Ho	< 0.05
Mn	< 0.05	Er	< 0.05
Fe	0.22	Tm	< 0.05
Co	< 0.05	Yb	< 0.05
Ni	< 0.1	Lu	< 0.05
Cu	< 0.1	Hf	< 0.05
Zn	< 0.1	Ta	< 5
Ga	< 0.1	W	0.45
Ge	< 0.1	Re	< 0.05
As	< 0.1	Os	< 0.05
Se	< 0.1	Ir	< 0.05
Br	< 0.1	Pt	< 0.05
Rb	< 0.05	Au	< 0.1
Sr	< 0.05	Hg	< 0.5
Y	0.09	Tl	< 0.1
Zr	1.3	Pb	< 0.5
Nb	< 0.1	Bi	< 0.1
Mo	0.17	Th	< 0.05
Ru	< 0.1	U	< 0.05
Rh	< 0.1		

J.SCHIEBLER (Analyst)

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Table 6-4. Impurity analysis report for heat-treated compact A3-P43-Z15

EAG Evans Analytical Group

GDMS
ANALYTICAL REPORT

SHIVA Technologies
An Operating Unit of Evans Analytical Group LLC
6707 Brooklawn Parkway
Syracuse, New York 13211

Telephone (315) 431-9900
Fax: (315) 431-9800
Email info.ny@eaglabs.com
www.eaglabs.com

Customer: **UT-Battelle Oak Ridge**
1 Bethel Valley Rd, Oak Ridge, TN 37823-6063 USA
P.O.# **4000100480**

Date: 8-Nov-10
Job # S0ABV776

Customer ID: **C**
A3-P43-Z15
Sample ID: S101101074

Element	Concentration [ppm wt]	Element	Concentration [ppm wt]
Li	< 0.01	Pd	< 0.1
Be	< 0.01	Ag	< 0.1
B	0.12	Cd	< 0.1
C	Matrix	In	< 0.1
N	-	Sn	< 0.5
O	-	Sb	< 0.5
F	< 1	Te	< 0.1
Na	< 0.05	I	< 0.1
Mg	10	Cs	< 0.1
Al	23	Ba	0.17
Si	480	La	< 0.5
P	1.1	Ce	< 0.05
S	35	Pr	< 0.05
Cl	0.16	Nd	< 0.05
K	< 0.1	Sm	< 0.05
Ca	25	Eu	< 0.05
Sc	< 0.05	Gd	< 0.05
Ti	1.1	Tb	< 0.05
V	0.88	Dy	< 0.05
Cr	< 0.5	Ho	< 0.05
Mn	< 0.05	Er	< 0.05
Fe	0.08	Tm	< 0.05
Co	< 0.05	Yb	< 0.05
Ni	< 0.1	Lu	< 0.05
Cu	< 0.1	Hf	< 0.05
Zn	< 0.1	Ta	< 5
Ga	< 0.1	W	0.35
Ge	< 0.1	Re	< 0.05
As	< 0.1	Os	< 0.05
Se	< 0.1	Ir	< 0.05
Br	< 0.1	Pt	< 0.05
Rb	< 0.05	Au	< 0.1
Sr	< 0.05	Hg	< 0.5
Y	< 0.05	Tl	< 0.1
Zr	0.89	Pb	< 0.5
Nb	< 0.1	Bi	< 0.1
Mo	0.17	Th	< 0.05
Ru	< 0.1	U	< 0.05
Rh	< 0.1		

J.SCHIEBLER (Analyst)

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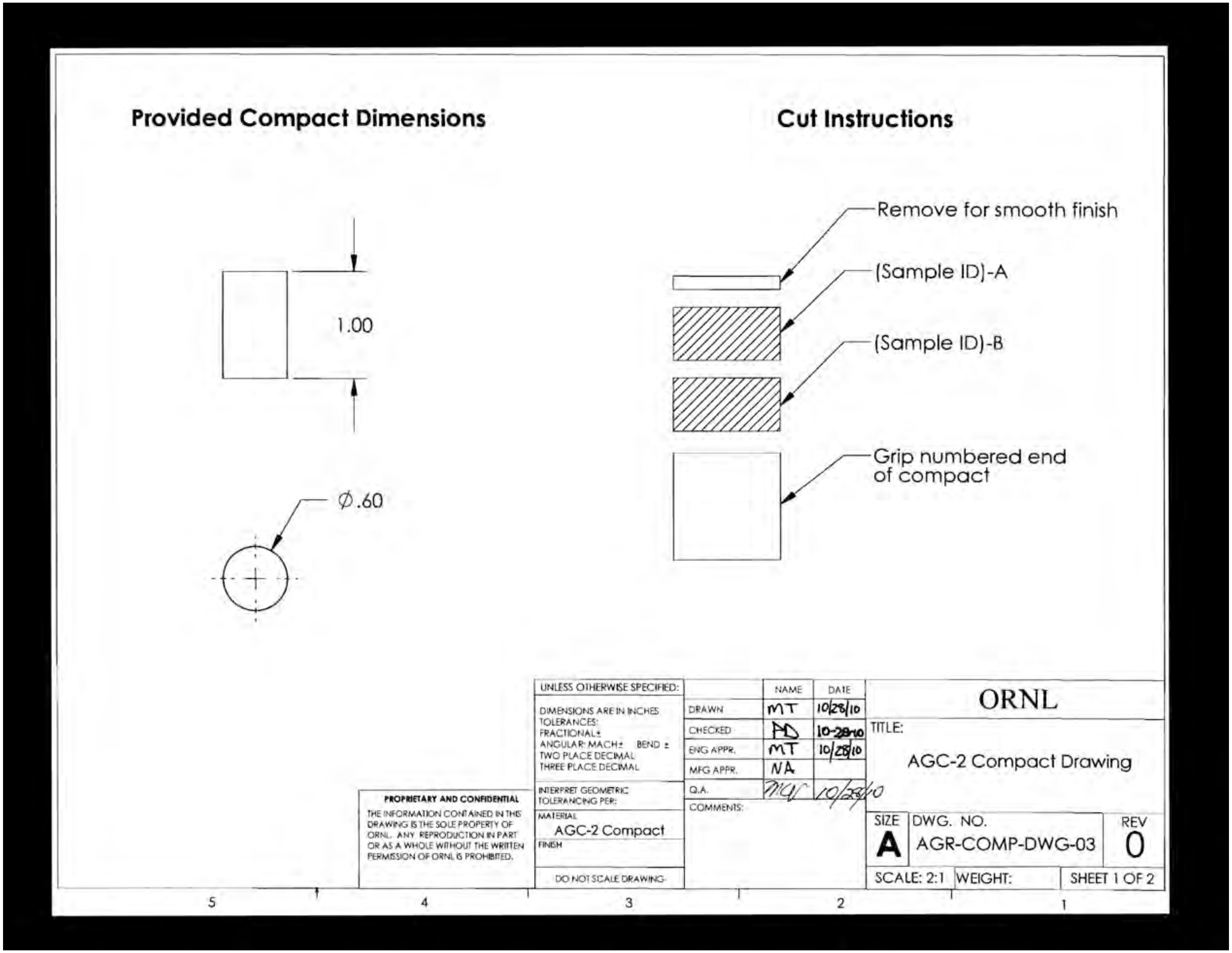
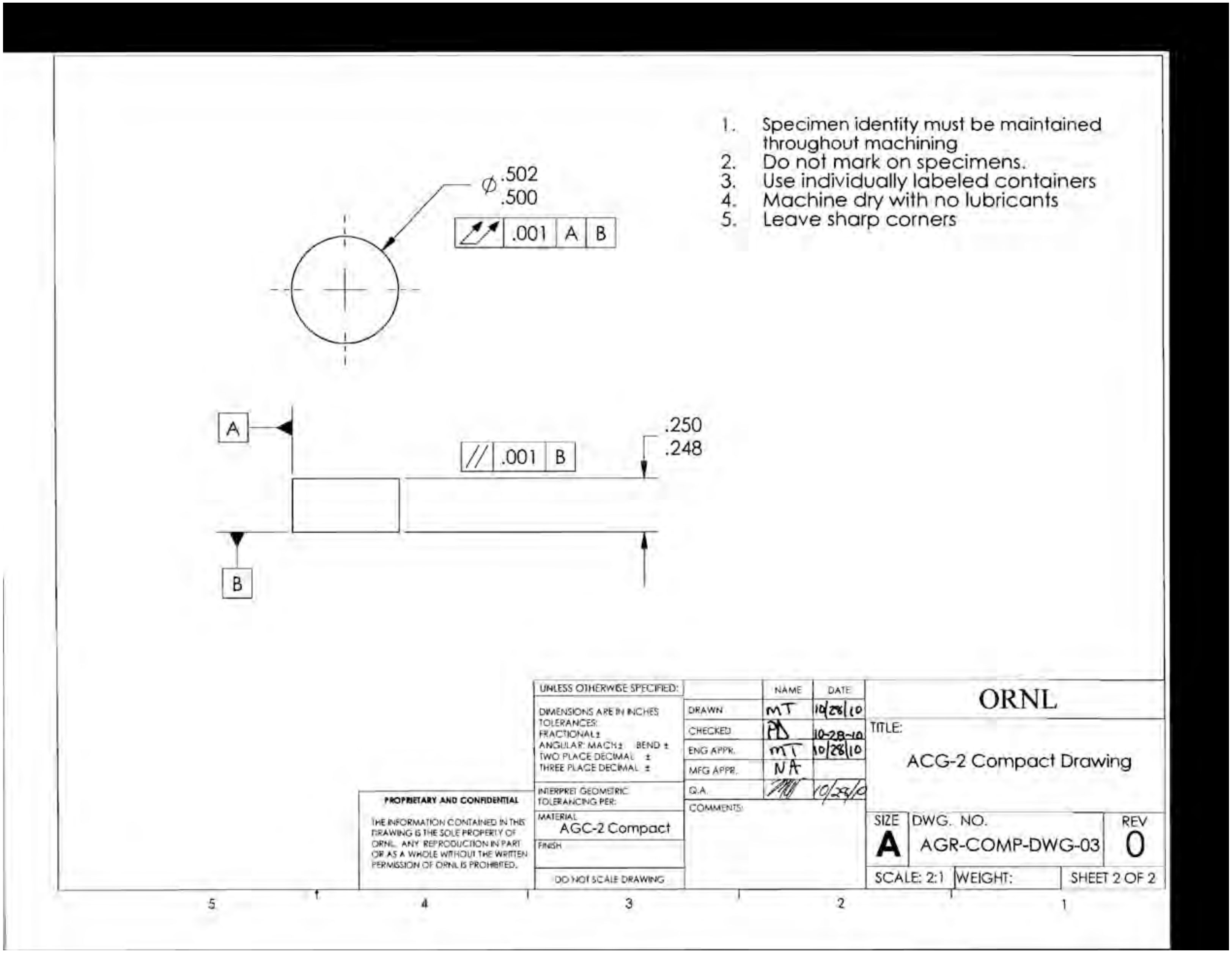
Appendix A: Compact Machining Drawings

Prior to heat-treatment, carbonized cylinders were machined according to drawing AGR-COMP-DWG-03, “AGC Compact Drawing”. Copies of these drawings are attached in this appendix.


Provided Compact Dimensions
1.00
Ø.60
Cut Instructions
Remove for smooth finish
(Sample ID)-A
(Sample ID)-B
Grip numbered end of compact
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL
THREE PLACE DECIMAL
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AGC-2 Compact
FINISH
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF ORNL. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF ORNL IS PROHIBITED.
NAME
DATE
DRAWN
MT
10/28/10
CHECKED
ENG APPR.
MT
10/28/10
MFG APPR.
NA
Q.A.
COMMENTS:
ORNL
TITLE:
AGC-2 Compact Drawing
SIZE
A
DWG. NO.
AGR-COMP-DWG-03
REV
0
SCALE: 2:1
WEIGHT:
SHEET 1 OF 2
5
4
3
2
1


1. Specimen identity must be maintained throughout machining
2. Do not mark on specimens.
3. Use individually labeled containers
4. Machine dry with no lubricants
5. Leave sharp corners
∅ .502 .500
.001 A B
A
// .001 B
.250 .248
B
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AGC-2 Compact
FINISH
DO NOT SCALE DRAWING
NAME DATE
DRAWN MT 10/28/10
CHECKED 10-28-10
ENG APPR. MT 10/28/10
MFG APPR. NA
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF ORNL. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF ORNL IS PROHIBITED.
ORNL
TITLE:
ACG-2 Compact Drawing
SIZE A
DWG. NO. AGR-COMP-DWG-03
REV 0
SCALE: 2:1 WEIGHT: SHEET 2 OF 2
5 4 3 2 1

Appendix B: Certificate of Conformance

This section contains the Certificate of Conformance for the A3-P43 compact lot. This is a record of the review by Quality Assurance personnel that specified requirements in INL SPC-1285, Rev. 1 have been met. All compacts selected for irradiation or impurity analysis met all dimensional and density specifications. Note that the specification only requires compacts used for irradiation meet these requirements, so the final determination of this inspection is that the product (compacts used for irradiation) conforms to the specified requirements for length, diameter, and density.

Oak Ridge National Laboratory
Advanced Gas Reactor Fuel Development and Qualification Program
CERTIFICATE OF CONFORMANCE

1. ITEM IDENTIFICATION: AGC-2 Matrix-only Compacts
2. PART LOT AND LOT NUMBER: INL Blend D with Plenco 14043, Lot A3-P43
3. PRODUCT DEFINITION: INL SPC-1285, Revision 1, *Matrix Compacts for AGC-2 Irradiation*
4. LIST OF APPROVED DEVIATIONS: Not Applicable

*Part Type	Unique Part I.D. No.	QTY	INIT.	Date	*Part Type	Unique Part I.D. No.	QTY	INIT.	Date
MC	A3-P43-Z03	1	MCV	11/11/10					
MC	A3-P43-Z12	1	MCV	11/10/10					
MC	A3-P43-Z06	1	MCV	11/11/10					

5. LIST OF APPLICABLE NONCONFORMANCE REPORT NUMBERS: Not Applicable

With the exception of the Deviations documented on the forms referenced in Item 4 and the nonconforming conditions documented on Nonconformance Reports referenced in Item 5, the listed parts have been produced and tested in compliance to the requirements of the QAP for the AGR Program at ORNL (Document # QAP-ORNL-AGR-01), its subordinate implementing procedures, and to the specified product definition prescribed in the document(s) referenced in Item 3.

M. C. Vance, AGR Quality Representative,
Fuel Cycle and Isotopes Division, ORNL

11/11/10
Date

* MC indicates matrix-only compact