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ORNL/TM-2006/507

Data Compilation for AGR-1 Baseline Compact Lot LEU01-46T-Z

Revision 0

John D. Hunn, Fred C. Montgomery and Peter J. Pappano

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Data Compilation for AGR-1 Baseline Compact Lot LEU01-46T-Z

J. D. Hunn, F. C. Montgomery and P. J. Pappano
Oak Ridge National Laboratory

This document is a compilation of characterization data for the AGR-1 baseline compact lot LEU01-46T-Z. The compacts were produced by ORNL for the Advanced Gas Reactor Fuel Development and Qualification (AGR) program for the first AGR irradiation test train (AGR-1). This compact lot was fabricated using particle composite LEU01-46T, which was a composite of four batches of TRISO-coated 350 μm diameter 19.7% low enrichment uranium oxide/uranium carbide kernels (LEUCO). The AGR-1 TRISO-coated particles consist of a spherical kernel coated with an ~50% dense carbon buffer layer (100 μm nominal thickness), followed by a dense inner pyrocarbon layer (40 μm nominal thickness), followed by a SiC layer (35 μm nominal thickness), followed by another dense outer pyrocarbon layer (40 μm nominal thickness). The kernels were obtained from BWXT and identified as composite G73D-20-69302. The BWXT kernel lot G73D-20-69302 was riffled into sublots for characterization and coating by ORNL and identified as LEU01-## (where ## is a series of integers beginning with 01). A data compilation for the AGR-1 baseline coated particle composite LEU01-46T can be found in ORNL/TM-2006/019.

The AGR-1 Fuel Product Specification and Characterization Guidance (INL EDF-4380) provides the requirements necessary for acceptance of the fuel manufactured for the AGR-1 irradiation test. Section 6.2 of EDF-4380 provides the property requirements for the heat treated compacts. The Statistical Sampling Plan for AGR Fuel Materials (INL EDF-4542) provides additional guidance regarding statistical methods for product acceptance and recommended sample sizes. The procedures for characterizing and qualifying the compacts are outlined in ORNL product inspection plan AGR-CHAR-PIP-05. The inspection report forms generated by this product inspection plan document the product acceptance for the property requirements listed in section 6.2 of EDF-4380.

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1 Summary of acceptance test results for LEU01-46T-Z

This section contains inspection report forms (IRFs) associated with the compact lot LEU01-46T-Z. These inspection report forms also appear in a later section of this compilation, accompanied by the associated data report forms (DRFs) showing the results of each individual measurement. These inspection report forms summarize the acceptance testing performed according to the product inspection plan AGR-CHAR-PIP-05. The information in these forms covers all the property specifications listed in section 6.2 of the AGR-1 Fuel Product Specification and Characterization Guidance document INL EDF-4380, Rev. 8. The compact lot, LEU01-46T-Z, was found to meet all the requirements in section 6.2 of EDF-4380, Rev. 8 with the exception of 19 compacts which were available for irradiation that did not meet the specified minimum length. These 19 non-conforming compacts have been dispositioned for use as is by NCR-X-AGR-06-03.

Table 1-1 is provided for quick reference. It gives the mean values of key variable properties of the compact lot, LEU01-46T-Z. For standard deviations of the distribution of the measured values see the appropriate IRF or DRF. For discussions on the uncertainty in these values, see the associated data acquisition methods and data report forms.

Table 1-1: Quick reference table for key variable properties of LEU01-46T-Z.

Property	Mean
Mean uranium loading (g U/compact)	0.917
Compact diameter (mm)	12.37
Compact length (mm)	25.05
Compact mass (g)	5.482
Impurity content	Table 1-2

The mean impurity levels for the fuel compacts reported on IRF-05A and IRF-05B are probably higher than the actual values for two reasons. First, the as-reported mean impurity levels do not reflect the fact that some of the measurements were at or below the measurement threshold and could not be differentiated from zero. Second, the as-reported mean impurity levels do not account for impurities introduced during the analysis.

Each time a leach was performed, a blank run was also performed where all the relevant wet chemistry steps in the leach-burn-leach procedure in AGR-CHAR-DAM-26R0 were performed without a compact present in order to obtain background values for the analyzed impurities. Table 1-2 shows the total as-reported mean and standard deviation for each measured impurity as well as the total mean values adjusted by subtracting the background values obtained from the associated blank runs. In cases where the value for the blank run was reported as being below a certain measurement threshold value, a minimum value for that leach was calculated by subtracting the threshold value and a maximum value was calculated by subtracting zero. The adjusted mean therefore accounts for all the measurable impurities in the blanks and spans a range that reflects the uncertainty due to the measurement thresholds.

Table 1-2: Mean impurity levels for fuel compacts from LEU-46T-Z compact lot measured by deconsolidation leach-burn-leach technique.

Measured Impurity	As-reported Mean	Adjusted Mean	
		Mininum	Maximum
Fe outside SiC (µg/compact):	2.97 ± 0.56	1.46 ± 0.72	1.57 ± 0.59
Cr outside SiC (µg/compact):	1.58 ± 0.02	0.00 ± 0.00	1.58 ± 0.02
Mn outside SiC (µg/compact):	0.42 ± 0.08	0.02 ± 0.04	0.12 ± 0.03
Co outside SiC (µg/compact):	0.63 ± 0.01	0.00 ± 0.00	0.63 ± 0.01
Ni outside SiC (µg/compact):	1.20 ± 0.11	0.08 ± 0.10	1.20 ± 0.11
Cr+Mn+Co+Ni outside SiC (µg/compact):	3.82 ± 0.19	0.10 ± 0.14	3.53 ± 0.17
Ca outside SiC (µg/compact):	14.77 ± 1.91	7.45 ± 1.90	7.95 ± 1.92
Al outside SiC (µg/compact):	10.28 ± 1.51	3.84 ± 1.35	8.54 ± 1.16
Ti outside SiC (µg/compact):	9.00 ± 1.17	6.39 ± 1.00	6.96 ± 1.00
V outside SiC (µg/compact):	18.20 ± 1.42	17.28 ± 1.45	18.20 ± 1.42
Ti + V outside SiC (µg/compact):	27.20 ± 2.33	23.67 ± 2.13	25.15 ± 2.11

Table 1-3 is also provided for quick reference. It gives the upper limit of the 95% confidence interval of the defect fraction for key attribute properties of the compact lot LEU01-46T-Z. In other words, these values are the lowest tolerance limits for which the compact lot would be deemed acceptable at 95% confidence based on the particular sample that was measured. For the actual number of trials and number of failures observed, see the inspection report form for the compact lot.

Table 1-3: Quick reference table for key attribute properties of LEU01-46T-Z.

Property	Defect Fraction
Uranium contamination fraction	$\leq 3.1 \cdot 10^{-5}$
Defective SiC coating fraction	$\leq 1.3 \cdot 10^{-4}$
Defective IPyC coating fraction	$\leq 6.1 \cdot 10^{-5}$
Defective OPyC coating fraction	$\leq 7.3 \cdot 10^{-4}$

Also worthy of note is the observation of particles with SiC layers less than 20 μm thick. These were observed and noted for information only during x-ray analysis for uranium dispersion after compacting due to defective IPyC. In terms of the upper limit of the 95% confidence interval of the anomaly fraction, as reported in Table 1-3, the fraction of particles in the compact lot with SiC <20 μm thick is $\leq 4.7 \cdot 10^{-4}$. This anomaly is probably caused by particles being temporarily trapped in carbon soot that has built up on the walls of the coating chamber above the fluidized particle bed. This is the same mechanism thought to cause soot inclusions (goldspots) within the SiC layer.

DRF-24 indicates that 30 compacts failed to meet the length specification, being shorter than the lower acceptance limit of 25.02 mm. Of the 30 compacts that were shorter than 25.02 mm, 11 were selected for destructive characterization according to AGR-CHAR-PIP-05R0. The remaining 19 compacts that were shorter than 25.02 mm were available for irradiation and dispositioned for use as is by NCR-X-AGR-06-03. Table 1-4 lists the compacts that are available for irradiation sorted in order of increasing length.

Table 1-4: Compacts from LEU-46T-Z compact lot available for irradiation sorted by length

Compact ID Number	Length (mm)	Diameter (mm)						Pass Thru? (Y or N)	Mass (g)	Accept? (pass or fail)
		Top 1	Top 2	Middle 1	Middle 2	Bottom 1	Bottom 2			
03	24.857	12.40	12.41	12.41	12.41	12.41	12.41	Y	5.4757	fail
68	24.928	12.37	12.36	12.37	12.37	12.36	12.36	Y	5.4756	fail
37	24.938	12.38	12.37	12.37	12.37	12.36	12.36	Y	5.4757	fail
38	24.941	12.37	12.37	12.38	12.38	12.37	12.38	Y	5.4797	fail
76	24.942	12.37	12.37	12.37	12.37	12.36	12.37	Y	5.4706	fail
78	24.960	12.36	12.36	12.36	12.37	12.36	12.36	Y	5.4374	fail
18	24.960	12.37	12.37	12.38	12.37	12.36	12.36	Y	5.4730	fail
12	24.985	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4890	fail
79	24.985	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4721	fail
27	24.992	12.38	12.38	12.38	12.38	12.36	12.36	Y	5.4936	fail
23	24.994	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4814	fail
74	24.996	12.37	12.37	12.38	12.38	12.36	12.36	Y	5.4793	fail
77	24.997	12.36	12.37	12.37	12.37	12.36	12.36	Y	5.4648	fail
14	24.997	12.37	12.37	12.37	12.36	12.36	12.36	Y	5.4797	fail
67	25.001	12.36	12.36	12.36	12.36	12.35	12.36	Y	5.4546	fail
20	25.003	12.38	12.38	12.38	12.38	12.37	12.37	Y	5.4855	fail
32	25.005	12.37	12.37	12.37	12.37	12.37	12.36	Y	5.4732	fail
07	25.006	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4676	fail
09	25.013	12.37	12.37	12.37	12.37	12.35	12.36	Y	5.4786	fail
53	25.022	12.37	12.37	12.37	12.37	12.37	12.36	Y	5.4877	pass
24	25.022	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4810	pass
44	25.027	12.37	12.37	12.36	12.37	12.37	12.36	Y	5.4851	pass
15	25.030	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4835	pass
36	25.031	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4655	pass
65	25.032	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4856	pass
69	25.036	12.37	12.37	12.37	12.37	12.35	12.36	Y	5.4695	pass
47	25.041	12.37	12.37	12.37	12.37	12.37	12.37	Y	5.4802	pass
22	25.053	12.38	12.37	12.37	12.38	12.36	12.37	Y	5.4980	pass
42	25.059	12.37	12.37	12.36	12.36	12.35	12.36	Y	5.4867	pass
55	25.065	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4907	pass
56	25.073	12.37	12.36	12.37	12.37	12.36	12.37	Y	5.4913	pass
58	25.073	12.36	12.36	12.36	12.36	12.35	12.35	Y	5.4760	pass
46	25.074	12.36	12.36	12.36	12.36	12.35	12.35	Y	5.4631	pass
17	25.074	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4861	pass
49	25.090	12.37	12.37	12.37	12.37	12.37	12.36	Y	5.4791	pass
34	25.097	12.37	12.36	12.37	12.36	12.36	12.36	Y	5.4893	pass
33	25.109	12.37	12.37	12.37	12.37	12.37	12.36	Y	5.5023	pass
29	25.114	12.38	12.38	12.38	12.38	12.37	12.36	Y	5.4826	pass
30	25.115	12.37	12.36	12.37	12.37	12.35	12.36	Y	5.4756	pass
43	25.133	12.37	12.36	12.36	12.37	12.36	12.36	Y	5.4941	pass
62	25.135	12.36	12.36	12.36	12.36	12.35	12.35	Y	5.4719	pass
50	25.140	12.37	12.37	12.37	12.37	12.36	12.35	Y	5.4843	pass
57	25.142	12.36	12.36	12.37	12.37	12.35	12.35	Y	5.4829	pass
52	25.143	12.36	12.36	12.36	12.36	12.36	12.35	Y	5.4792	pass
39	25.147	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.5035	pass
60	25.250	12.36	12.36	12.36	12.36	12.36	12.35	Y	5.4757	pass
19	25.256	12.36	12.37	12.36	12.36	12.35	12.35	Y	5.4874	pass
05	25.264	12.36	12.36	12.36	12.36	12.35	12.36	Y	5.4779	pass

Inspection Report Form IRF-05A: Fuel Compact Lots

Procedure:	AGR-CHAR-PIP-05 Rev. 0
Compact lot ID:	LEU01-46T-Z
Compact lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T
Compact ID numbers of compacts available for irradiation test (pending acceptance):	03,05,07,09,12,14,15,17,18,19,20,22,23,24,27,29,30,32,33,34,36,37,38,39 42,43,44,46,47,49,50,52,53,55,56,57,58,60,62,65,67,68,69,74,76,77,78,79

Property	Measured Data Mean (x)	Std. Dev. (s)	Measurements (n)	k or t value	Specification INL EDF-4380 Rev. 8	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
Compact diameter (mm)	See DRF-24				12.22 - 12.46	all available for irradiation test meet specification		pass (Note 1)	DRF-24
Compact length (mm)					25.02 - 25.40				
Uranium loading (gU/compact)	0.917	0.005	6	2.015	0.905 ± 0.04	$A = x - ts/\sqrt{n} \geq 0.865$	0.913	pass	DRF-25
						$B = x + ts/\sqrt{n} \leq 0.945$	0.921	pass	
Iron content outside SiC (µg/compact)	2.97	0.56	4	2.353	mean ≤ 25	$B = x + ts/\sqrt{n} \leq 25$	3.6	pass	IRF-05B DRF-26
				7.042	dispersion ≤0.01 ≥ 100	$D = x + \sqrt{3}ks < 100$	9.8	pass	
Chromium content outside SiC (µg/compact)	1.58	0.02	4	2.353	mean ≤ 75	$B = x + ts/\sqrt{n} \leq 75$	1.6	pass	IRF-05B DRF-26
Manganese content outside SiC (µg/compact)	0.42	0.08	4	2.353	mean ≤ 75	$B = x + ts/\sqrt{n} \leq 75$	0.5	pass	IRF-05B DRF-26
Cobalt content outside SiC (µg/compact)	0.63	0.01	4	2.353	mean ≤ 75	$B = x + ts/\sqrt{n} \leq 75$	0.6	pass	IRF-05B DRF-26
Nickel content outside SiC (µg/compact)	1.20	0.11	4	2.353	mean ≤ 75	$B = x + ts/\sqrt{n} \leq 75$	1.3	pass	IRF-05B DRF-26
Cr + Mn + Co + Ni content outside SiC (µg/compact)	3.82	0.19	4	7.042	dispersion ≤0.01 ≥ 300	$D = x + \sqrt{3}ks < 300$	6.1	pass	IRF-05B DRF-26
Calcium content outside SiC (µg/compact)	14.77	1.91	4	2.353	mean ≤ 90	$B = x + ts/\sqrt{n} \leq 90$	17.0	pass	IRF-05B DRF-26
Aluminum content outside SiC (µg/compact)	10.28	1.51	4	2.353	mean ≤ 45	$B = x + ts/\sqrt{n} \leq 45$	12.1	pass	IRF-05B DRF-26
Ti + V content outside SiC (µg/compact)	27.20	2.33	4	2.353	mean ≤ 400	$B = x + ts/\sqrt{n} \leq 400$	29.9	pass	IRF-05B DRF-26

Property	Measured Data # of compacts	# of particles	Specification INL EDF-4380	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
Uranium contamination fraction (g exposed U/gram U in compact)	24	99470	$\leq 1.0 \times 10^{-4}$	≤4 effectively exposed kernels in ≥91533 particles	0	pass	IRF-05C DRF-26
Defective SiC coating fraction (fraction of total particles)	12	49735	$\leq 2.0 \times 10^{-4}$	≤4 leached kernels in ≥45766 particles or ≤12 leached kernels in ≥97210 particles	2	pass	IRF-05D DRF-26
Defective IPyC coating fraction (fraction of total particles)	12	49735	$\leq 2.0 \times 10^{-4}$	≤4 with excessive U dispersion in ≥45766 particles or ≤12 with excessive U dispersion in ≥97210 particles	0	pass	DRF-28
Defective OPyC coating fraction (fraction of total particles)	1	4145	≤ 0.01	≤6 cracked or missing OPyC in ≥1182 particles or ≤30 cracked or missing OPyC in ≥4064 particles	0	pass	DRF-27

Comments

Note 1: 19 compacts in lot LEU01-46T-Z listed above as available for irradiation were below 25.02 mm in length, these were accepted for use as is per NCR-X-AGR-06-03.
Note 2: Per EDF-4380, a specification on Cl content outside SiC is not applicable because HCl cleaning of compacts was not performed.

John Hunn
QC Supervisor

7-19-06
Date

Accept compact lot (Yes or No):	Yes

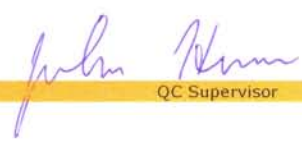
M. C. Teague
QA Reviewer

7/19/06
Date

Inspection Report Form IRF-05B: Summary of Impurites Outside SiC

Procedure:	AGR-CHAR-PIP-05 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact Lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T

Compact ID numbers:	10, 13, 66	40, 48, 64	35, 54, 59	08, 26, 75	Mean	Standard Deviation
Number of compacts:	3	3	3	3		
Iron						
Deconsolidation-leach (DRF-26A) (µg):	5.15	5.86	8.87	4.85		
Burn-leach (DRF-26B) (µg):	1.89	2.08	1.46	5.47		
Total leached (µg):	7.04	7.94	10.33	10.32		
Fe outside SiC (µg/compact):	**2.35**	**2.65**	**3.44**	**3.44**	**2.97**	**0.56**
Chromium						
Deconsolidation-leach (DRF-26A) (µg):	3.36	3.38	3.36	3.22		
Burn-leach (DRF-26B) (µg):	1.41	1.41	1.41	1.41		
Total leached (µg):	4.77	4.79	4.77	4.63		
Cr outside SiC (µg/compact):	**1.59**	**1.60**	**1.59**	**1.54**	**1.58**	**0.02**
Manganese						
Deconsolidation-leach (DRF-26A) (µg):	0.85	0.86	1.19	1.11		
Burn-leach (DRF-26B) (µg):	0.20	0.20	0.37	0.20		
Total leached (µg):	1.05	1.07	1.56	1.32		
Mn outside SiC (µg/compact):	**0.35**	**0.36**	**0.52**	**0.44**	**0.42**	**0.08**
Cobalt						
Deconsolidation-leach (DRF-26A) (µg):	1.34	1.35	1.34	1.28		
Burn-leach (DRF-26B) (µg):	0.56	0.56	0.56	0.56		
Total leached (µg):	1.90	1.92	1.90	1.85		
Co outside SiC (µg/compact):	**0.63**	**0.64**	**0.63**	**0.62**	**0.63**	**0.01**
Nickel						
Deconsolidation-leach (DRF-26A) (µg):	2.38	2.40	2.38	2.28		
Burn-leach (DRF-26B) (µg):	1.00	1.26	1.66	1.00		
Total leached (µg):	3.38	3.66	4.04	3.28		
Ni outside SiC (µg/compact):	**1.13**	**1.22**	**1.35**	**1.09**	**1.20**	**0.11**
Transition Metals						
Cr+Mn+Co+Ni outside SiC (µg/compact):	**3.70**	**3.81**	**4.09**	**3.69**	**3.82**	**0.19**
Calcium						
Deconsolidation-leach (DRF-26A) (µg):	23.95	21.89	18.68	30.88		
Burn-leach (DRF-26B) (µg):	14.11	26.95	22.12	18.62		
Total leached (µg):	38.06	48.84	40.80	49.50		
Ca outside SiC (µg/compact):	**12.69**	**16.28**	**13.60**	**16.50**	**14.77**	**1.91**
Aluminum						
Deconsolidation-leach (DRF-26A) (µg):	19.53	18.16	15.96	27.00		
Burn-leach (DRF-26B) (µg):	14.13	14.83	8.14	5.62		
Total leached (µg):	33.66	32.99	24.10	32.62		
Al outside SiC (µg/compact):	**11.22**	**11.00**	**8.03**	**10.87**	**10.28**	**1.51**
Titanium						
Deconsolidation-leach (DRF-26A) (µg):	17.01	14.58	14.90	13.46		
Burn-leach (DRF-26B) (µg):	4.96	12.76	14.09	16.26		
Total leached (µg):	21.97	27.34	28.99	29.72		
Ti outside SiC (µg/compact):	**7.32**	**9.11**	**9.66**	**9.91**	**9.00**	**1.17**
Vanadium						
Deconsolidation-leach (DRF-26A) (µg):	29.60	28.43	30.98	30.26		
Burn-leach (DRF-26B) (µg):	22.51	21.42	27.54	27.60		
Total leached (µg):	52.11	49.85	58.52	57.86		
V outside SiC (µg/compact):	**17.37**	**16.62**	**19.51**	**19.29**	**18.20**	**1.42**
Titanium and Vanadium						
Ti + V outside SiC (µg/compact):	**24.69**	**25.73**	**29.17**	**29.19**	**27.20**	**2.33**



QC Supervisor

5-11-06

Date

Inspection Report Form IRF-05C: Summary of Uranium Contamination

Procedure:	AGR-CHAR-PIP-05 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact Lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T

Compact ID numbers:	10, 13, 66	40, 48, 64	35, 54, 59	08, 26, 75	02, 04, 11, 28, 31, 61	25, 41, 51, 63, 70, 73	Total
Number of compacts:	3	3	3	3	6	6	24
Effective number of exposed kernels:	0.0	0.0	0.0	0.0	0.0	0.0	0.0

John Thomas
QC Supervisor

5-11-06
Date

Inspection Report Form IRF-05D: Summary of SiC Burn-Leach Defects

Procedure:	AGR-CHAR-PIP-05 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact Lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T

Compact ID numbers:	10, 13, 66	40, 48, 64	35, 54, 59	08, 26, 75			Total
Number of compacts:	3	3	3	3			12
Number of leached kernels:	1	1	0	0			2

John Hunn
QC Supervisor

5-11-06
Date

2 Compacting process conditions

LEU01-46T TRISO (baseline) particles were received from the characterization group after removing particles for characterization according to AGR-CHAR-PIP-04R2, "Product Inspection Plan for Coated Particle Composites." Nineteen ~20 g aliquots were prepared via riffling, and one aliquot was used per overcoating run. Prior to overcoating, the particles were washed in methanol per procedure AGR-TRISOWASH-SOP-1, "Standard Operating Procedure for TRISO Particle Washing." Washing of particles prior to overcoating was adapted in order to help reduce the amount of contamination on the particles that may have been acquired during processing or general handling. The washing procedure was adopted from General Atomics' particle washing procedures.

After washing, the LEU01-46T particles were overcoated using matrix batch GKrS 121405. All of the aliquots were overcoated producing 396 g of +18 particles. "+18" particles are those that pass through an ASTM E11 No. 16 sieve (1.18 mm) but do not pass through and ASTM E11 No. 18 sieve (1.00 mm). This quantity of +18 particles was insufficient (based on assumed weight per overcoated particle data and past overcoating experience) to produce 79 compacts, so -18 overcoated particles (those particles that passed through an ASTM E11 No. 18 sieve) were rinsed with methanol in order to remove the overcoat, and subsequently re-overcoated. Prior to rinsing off the overcoat, overcoating of the -18 particles was performed in an attempt to increase the overcoat thickness enough such that +18 overcoated particles would be produced. However, the +18 overcoated particles achieved in this re-overcoating manner were different in color than the +18 overcoated particles achieved in a standard overcoating run, and were therefore considered undesirable. Overcoated particle color is not specified in the overcoating procedure, but the PI decided it was better to overcoat all the TRISO particles in the same manner in order to produce overcoated particles with properties as similar as possible. A standard overcoating run is when TRISO particles (as opposed to -18 particles that have already been partially overcoated) are overcoated until +18 particles are achieved. Overcoating of reclaimed TRISO particles (TRISO particles from rinsed overcoated particles) was continued until 537 g of +18 particles was produced.

The 537 g of +18 particles was then tabled and 410 g of +18 Bin 3 particles were recovered. "Bin 3" particles are those particles that end up in the third bin of the tabler; these are the most spherical of the +18 particles. 410 g of +18 Bin 3 overcoated particles was determined to be a sufficient quantity to produce at least 79 compacts, based on preliminary calculations.

Based on an average kernel weight of $2.42 \cdot 10^{-4}$ g and a wt% uranium of 0.9006 for the AGR-1 kernels, 4151 particles are needed in each compact to obtain a uranium loading of 0.905 g. The average +18 Bin 3 overcoated particle weight was measured (according to AGR-CHAR-DAM-22, "Data Acquisition Method for Estimation of Average Particle Weight") to be $1.16 \cdot 10^{-3}$ g. Using this value, a compact charge of 4.82 g of +18 Bin 3 overcoated particles would be required for a compact uranium loading of 0.905 g. As an alternate approach for calculating the compact charge, a quantity of +18 Bin 3 overcoated particles was rinsed and the ratio of overcoated particle weight to TRISO particle weight was determined to be 1.613. 4151 particles corresponds

to 3.018 g TRISO particles (given an average weight for AGR-1 baseline TRISO particles of $7.27 \cdot 10^{-4}$ g). Using this second approach, a compact charge of 4.87 g of +18 Bin 3 overcoated particles would be required for a compact uranium loading of 0.905 g. Based on these two determinations, an overcoated particle charge of 4.86 g was used to increase the probability that the actual uranium loading would be ≥ 0.905 g.

The 410 g quantity of +18 Bin 3 overcoated particles was rotary riffled into aliquots of approximately 4.50 g. Additional +18 Bin 3 overcoated particles were added to each aliquot by scoop sampling until the desired 4.86 g compact charge was reached. Compacts were then made from the 4.86 g aliquots. Steps were taken in the process to increase the malleability of the overcoat, which helped aid the compaction process, densify the compact, and create a smoother, less porous outer surface. A 0.40 g quantity of matrix powder was added to the compacting mold prior to the addition of overcoated particles. Another 0.40g quantity of matrix was added to the mold after addition of the overcoated particles, such that the overcoated particles were compressed between two matrix "end caps" during fabrication. The compact is pressed by applying force to a top ram. The presence of the end caps helps to buffer the particles during compacting, and also provides a smooth, sharp end in the green compact. The thickness of the end caps is difficult to determine because a cylindrical geometry is not likely. Overcoat matrix and end cap matrix can be expected to intertwine and particles may extend beyond the apparent end cap boundary evident at the compact surface. The top end cap thickness was estimated by measuring the approximate width of the unfueled region that could be observed on the compact surface. The average top end cap thickness for 5 compacts estimated by this method was 1.3-1.5 mm. The bottom end cap was not measured, but was slightly thicker than the top end cap.

84 AGR-1 baseline compacts were fabricated. All of the 84 green compacts were subsequently carbonized and heat treated. 79 compacts were selected from this batch of 84 and delivered to the characterization group. The selection of the 79 compacts for the characterization group was based on length measurements at each stage of compacting (green, carbonization, and heat-treatment), and visual inspection for surface irregularities.

AGR-1 Process Conditions

The AGR-1 process limits from EDF-4380, Rev. 8 are listed below.

AGR-1 Process Limits: Molding Pressure <60 MPa

Carbonization parameters: <350ºC/hr in He
Hold at 950 ± 50ºC for 1.0 ± 0.4 hr
Furnace cool

Heat treatment parameters: ~20ºC/min in vacuum
Hold at 1650-1850ºC for 60 ± 10 min
Furnace cool at ~20ºC/min to below 700ºC

Table 2-1 shows the process conditions used in molding the compacts, carbonizing the compacts, and heat treating the compacts. In the carbonization regime, the furnace was allowed to cool under no power (i.e., after holding at 950°C for 1 hour, power was turned off). In the heat treatment run, the furnace was cooled under power until the furnace temperature reached 700°C. The rate of cooling was 20°C/min.

Conclusion

The LEU01-46T-Z (AGR-1 baseline) compact lot was made in accordance with the AGR-1 process limits listed in EDF-4380, Rev. 8.

Table 2-1: Summary of process conditions used in making LEU01-46T-Z (AGR-1 baseline) compacts

		Carbonization Parameter				Heat-treatment Parameters			
Compact ID	Molding Pressure (MPa)	Heating Rate (°C/min.)	Max. Temp. (°C)	Hold Time (hrs.)	Atmosphere	Heating Rate (°C/min.)	Max. Temp. (°C)	Hold Time (hrs.)	Atmosphere
LEU01-46T-Z01	13.92	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z02	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z03	22.28	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z04	13.00	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z05	11.14	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z06	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z07	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z08	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z09	13.92	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z10	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z11	13.00	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z12	13.92	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z13	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z14	13.92	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z15	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z16	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z17	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z18	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z19	11.14	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z20	15.78	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z21	15.78	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z22	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z23	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z24	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z25	13.92	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z26	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z27	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z28	12.07	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z29	13.92	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z30	12.07	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z31	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z32	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z33	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z34	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z35	13.92	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z36	13.92	4.7	950	1	flowing He	20	1800	1	vacuum

Task Manager Review Peter J. Pappano Date 8-1-06

QAS Review [signature] Date 8/1/06

Table 2-1 (cont.). Summary of process conditions used in making LEU01-46T-Z (AGR-1 baseline) compacts

		Carbonization Parameter				Heat-treatment Parameters			
Compact ID	Molding Pressure (MPa)	Heating Rate (°C/min.)	Max. Temp. (°C)	Hold Time (hrs.)	Atmosphere	Heating Rate (°C/min.)	Max. Temp. (°C)	Hold Time (hrs.)	Atmosphere
LEU01-46T-Z37	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z38	29.71	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z39	12.07	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z40	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z41	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z42	13.92	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z43	12.07	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z44	13.92	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z45	13.92	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z46	13.00	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z47	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z48	16.71	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z49	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z50	13.00	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z51	13.00	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z52	13.00	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z53	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z54	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z55	13.00	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z56	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z57	13.00	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z58	13.00	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z59	13.00	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z60	11.14	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z61	13.92	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z62	13.00	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z63	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z64	16.71	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z65	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z66	13.92	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z67	13.00	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z68	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z69	13.92	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z70	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z71	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z72	13.92	4.7	950	1	flowing He	20	1800	1	vacuum

Task Manager Review Peter J. Pappano Date 8-1-06

QAS Review Date 8/1/06

Table 2-1 (cont.). Summary of process conditions used in making LEU01-46T-Z (AGR-1 baseline) compacts

		Carbonization Parameter				Heat-treatment Parameters			
Compact ID	Molding Pressure (MPa)	Heating Rate (°C/min.)	Max. Temp. (°C)	Hold Time (hrs.)	Atmosphere	Heating Rate (°C/min.)	Max. Temp. (°C)	Hold Time (hrs.)	Atmosphere
LEU01-46T-Z73	11.14	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z74	15.78	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z75	14.85	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z76	13.92	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z77	13.00	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z78	13.92	4.7	950	1	flowing He	20	1800	1	vacuum
LEU01-46T-Z79	13.92	4.7	950	1	flowing He	20	1800	1	vacuum

Task Manager Review Peter J Pappano Date 8-1-06

QAS Review Date 8/1/06

3 Characterization of compacts

This section contains acceptance testing data on the compact lot LEU01-46T-Z. The data was obtained according to product inspection plan AGR-CHAR-PIP-05R0.

The following pages show the inspection report forms (IRF-05A, IRF-05B, IRF-05C, IRF-05D) for the LEU01-46T-Z compacts. Following the IRF-05 inspection report forms are the individual data report forms for the measurements that were performed. This compact lot was determined to satisfy the specifications in section 6.2 of the AGR-1 Fuel Product Specification and Characterization Guidance document INL EDF-4380, Rev. 8, with the exception of 19 compacts which were available for irradiation that did not meet the specified minimum length. These 19 non-conforming compacts have been dispositioned for use as is by NCR-X-AGR-06-03.

Inspection Report Form IRF-05A: Fuel Compact Lots

Procedure:	AGR-CHAR-PIP-05 Rev. 0
Compact lot ID:	LEU01-46T-Z
Compact lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T
Compact ID numbers of compacts available for irradiation test (pending acceptance):	03,05,07,09,12,14,15,17,18,19,20,22,23,24,27,29,30,32,33,34,36,37,38,39 42,43,44,46,47,49,50,52,53,55,56,57,58,60,62,65,67,68,69,74,76,77,78,79

Property	Measured Data Mean (x)	Std. Dev. (s)	Measurements (n)	k or t value	Specification INL EDF-4380 Rev. 8	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
Compact diameter (mm)	See DRF-24				12.22 - 12.46	all available for irradiation test meet specification		pass (Note 1)	DRF-24
Compact length (mm)					25.02 - 25.40				
Uranium loading (gU/compact)	0.917	0.005	6	2.015	0.905 ± 0.04	A = x - ts/√n ≥ 0.865	0.913	pass	DRF-25
						B = x + ts/√n ≤ 0.945	0.921	pass	
Iron content outside SiC (µg/compact)	2.97	0.56	4	2.353	mean ≤ 25	B = x + ts/√n ≤ 25	3.6	pass	IRF-05B DRF-26
				7.042	dispersion ≤0.01 ≥ 100	D = x + √3ks < 100	9.8	pass	
Chromium content outside SiC (µg/compact)	1.58	0.02	4	2.353	mean ≤ 75	B = x + ts/√n ≤ 75	1.6	pass	IRF-05B DRF-26
Manganese content outside SiC (µg/compact)	0.42	0.08	4	2.353	mean ≤ 75	B = x + ts/√n ≤ 75	0.5	pass	IRF-05B DRF-26
Cobalt content outside SiC (µg/compact)	0.63	0.01	4	2.353	mean ≤ 75	B = x + ts/√n ≤ 75	0.6	pass	IRF-05B DRF-26
Nickel content outside SiC (µg/compact)	1.20	0.11	4	2.353	mean ≤ 75	B = x + ts/√n ≤ 75	1.3	pass	IRF-05B DRF-26
Cr + Mn + Co + Ni content outside SiC (µg/compact)	3.82	0.19	4	7.042	dispersion ≤0.01 ≥ 300	D = x + √3ks < 300	6.1	pass	IRF-05B DRF-26
Calcium content outside SiC (µg/compact)	14.77	1.91	4	2.353	mean ≤ 90	B = x + ts/√n ≤ 90	17.0	pass	IRF-05B DRF-26
Aluminum content outside SiC (µg/compact)	10.28	1.51	4	2.353	mean ≤ 45	B = x + ts/√n ≤ 45	12.1	pass	IRF-05B DRF-26
Ti + V content outside SiC (µg/compact)	27.20	2.33	4	2.353	mean ≤ 400	B = x + ts/√n ≤ 400	29.9	pass	IRF-05B DRF-26

Property	Measured Data # of compacts	# of particles	Specification INL EDF-4380	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
Uranium contamination fraction (g exposed U/gram U in compact)	24	99470	≤ 1.0×10^{-4}	≤4 effectively exposed kernels in ≥91533 particles	0	pass	IRF-05C DRF-26
Defective SiC coating fraction (fraction of total particles)	12	49735	≤ 2.0×10^{-4}	≤4 leached kernels in ≥45766 particles or ≤12 leached kernels in ≥97210 particles	2	pass	IRF-05D DRF-26
Defective IPyC coating fraction (fraction of total particles)	12	49735	≤ 2.0×10^{-4}	≤4 with excessive U dispersion in ≥45766 particles or ≤12 with excessive U dispersion in ≥97210 particles	0	pass	DRF-28
Defective OPyC coating fraction (fraction of total particles)	1	4145	≤ 0.01	≤6 cracked or missing OPyC in ≥1182 particles or ≤30 cracked or missing OPyC in ≥4064 particles	0	pass	DRF-27

Comments

Note 1: 19 compacts in lot LEU01-46T-Z listed above as available for irradiation were below 25.02 mm in length, these were accepted for use as is per NCR-X-AGR-06-03.
Note 2: Per EDF-4380, a specification on Cl content outside SiC is not applicable because HCl cleaning of compacts was not performed.

QC Supervisor — Date: 7-19-06

Accept compact lot (Yes or No):	Yes

QA Reviewer — Date: 7/19/06

Inspection Report Form IRF-05B: Summary of Impurites Outside SiC

Procedure:	AGR-CHAR-PIP-05 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact Lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T

Compact ID numbers:	10, 13, 66	40, 48, 64	35, 54, 59	08, 26, 75	Mean	Standard Deviation
Number of compacts:	3	3	3	3		
Iron						
Deconsolidation-leach (DRF-26A) (µg):	5.15	5.86	8.87	4.85		
Burn-leach (DRF-26B) (µg):	1.89	2.08	1.46	5.47		
Total leached (µg):	7.04	7.94	10.33	10.32		
Fe outside SiC (µg/compact):	**2.35**	**2.65**	**3.44**	**3.44**	**2.97**	**0.56**
Chromium						
Deconsolidation-leach (DRF-26A) (µg):	3.36	3.38	3.36	3.22		
Burn-leach (DRF-26B) (µg):	1.41	1.41	1.41	1.41		
Total leached (µg):	4.77	4.79	4.77	4.63		
Cr outside SiC (µg/compact):	**1.59**	**1.60**	**1.59**	**1.54**	**1.58**	**0.02**
Manganese						
Deconsolidation-leach (DRF-26A) (µg):	0.85	0.86	1.19	1.11		
Burn-leach (DRF-26B) (µg):	0.20	0.20	0.37	0.20		
Total leached (µg):	1.05	1.07	1.56	1.32		
Mn outside SiC (µg/compact):	**0.35**	**0.36**	**0.52**	**0.44**	**0.42**	**0.08**
Cobalt						
Deconsolidation-leach (DRF-26A) (µg):	1.34	1.35	1.34	1.28		
Burn-leach (DRF-26B) (µg):	0.56	0.56	0.56	0.56		
Total leached (µg):	1.90	1.92	1.90	1.85		
Co outside SiC (µg/compact):	**0.63**	**0.64**	**0.63**	**0.62**	**0.63**	**0.01**
Nickel						
Deconsolidation-leach (DRF-26A) (µg):	2.38	2.40	2.38	2.28		
Burn-leach (DRF-26B) (µg):	1.00	1.26	1.66	1.00		
Total leached (µg):	3.38	3.66	4.04	3.28		
Ni outside SiC (µg/compact):	**1.13**	**1.22**	**1.35**	**1.09**	**1.20**	**0.11**
Transition Metals						
Cr+Mn+Co+Ni outside SiC (µg/compact):	**3.70**	**3.81**	**4.09**	**3.69**	**3.82**	**0.19**
Calcium						
Deconsolidation-leach (DRF-26A) (µg):	23.95	21.89	18.68	30.88		
Burn-leach (DRF-26B) (µg):	14.11	26.95	22.12	18.62		
Total leached (µg):	38.06	48.84	40.80	49.50		
Ca outside SiC (µg/compact):	**12.69**	**16.28**	**13.60**	**16.50**	**14.77**	**1.91**
Aluminum						
Deconsolidation-leach (DRF-26A) (µg):	19.53	18.16	15.96	27.00		
Burn-leach (DRF-26B) (µg):	14.13	14.83	8.14	5.62		
Total leached (µg):	33.66	32.99	24.10	32.62		
Al outside SiC (µg/compact):	**11.22**	**11.00**	**8.03**	**10.87**	**10.28**	**1.51**
Titanium						
Deconsolidation-leach (DRF-26A) (µg):	17.01	14.58	14.90	13.46		
Burn-leach (DRF-26B) (µg):	4.96	12.76	14.09	16.26		
Total leached (µg):	21.97	27.34	28.99	29.72		
Ti outside SiC (µg/compact):	**7.32**	**9.11**	**9.66**	**9.91**	**9.00**	**1.17**
Vanadium						
Deconsolidation-leach (DRF-26A) (µg):	29.60	28.43	30.98	30.26		
Burn-leach (DRF-26B) (µg):	22.51	21.42	27.54	27.60		
Total leached (µg):	52.11	49.85	58.52	57.86		
V outside SiC (µg/compact):	**17.37**	**16.62**	**19.51**	**19.29**	**18.20**	**1.42**
Titanium and Vanadium						
Ti + V outside SiC (µg/compact):	**24.69**	**25.73**	**29.17**	**29.19**	**27.20**	**2.33**

QC Supervisor

5-11-06

Date

Inspection Report Form IRF-05C: Summary of Uranium Contamination

Procedure:	AGR-CHAR-PIP-05 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact Lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T

Compact ID numbers:	10, 13, 66	40, 48, 64	35, 54, 59	08, 26, 75	02, 04, 11, 28, 31, 61	25, 41, 51, 63, 70, 73	Total
Number of compacts:	3	3	3	3	6	6	24
Effective number of exposed kernels:	0.0	0.0	0.0	0.0	0.0	0.0	0.0

QC Supervisor

5-11-06
Date

Inspection Report Form IRF-05D: Summary of SiC Burn-Leach Defects

Procedure:	AGR-CHAR-PIP-05 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact Lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T

Compact ID numbers:	10, 13, 66	40, 48, 64	35, 54, 59	08, 26, 75			Total
Number of compacts:	3	3	3	3			12
Number of leached kernels:	1	1	0	0			2

QC Supervisor

5-11-06

Date

Data Report Form DRF-24: Compact Diameter and Length

Procedure:	AGR-CHAR-DAM-24 Rev. 3
Operator:	Ivan Dunbar
Compact lot ID:	LEU01-46T-Z
Compact Lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T
Filename:	\\mc-agr\AGR\CompactDimensions\LEU01-46T-Z_DRF24R3.xls

Vertical height gauge calibration due date:	9/8/06
Pass-thru block calibration due date:	1/17/09
Digital caliper calibration due date:	9/8/06
Gauge blocks calibration due date:	9/8/06

Acceptance criteria for compact length:	≥25.02 and ≤25.40 mm
Acceptance criteria for compact diameter:	≥12.22 and ≤12.46 mm (and pass through 12.46 mm ring gauge)
Acceptance criteria for compact mass:	For information only

Compact ID Number	Length (mm)	Diameter (mm)						Pass Thru? (Y or N)	Mass (g)	Accept? (pass or fail)
		Top 1	Top 2	Middle 1	Middle 2	Bottom 1	Bottom 2			
01	25.128	12.37	12.38	12.37	12.37	12.37	12.36	Y	5.4794	pass
02	25.030	12.37	12.36	12.37	12.36	12.36	12.36	Y	5.4872	pass
03	24.857	12.40	12.41	12.41	12.41	12.41	12.41	Y	5.4757	fail
04	25.090	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4900	pass
05	25.264	12.36	12.36	12.36	12.36	12.35	12.36	Y	5.4779	pass
06	24.999	12.37	12.36	12.36	12.36	12.36	12.36	Y	5.4878	fail
07	25.006	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4676	fail
08	25.012	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4863	fail
09	25.013	12.37	12.37	12.37	12.37	12.35	12.36	Y	5.4786	fail
10	25.006	12.38	12.37	12.37	12.37	12.36	12.37	Y	5.4874	fail
11	25.100	12.37	12.37	12.38	12.37	12.36	12.37	Y	5.4893	pass
12	24.985	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4890	fail
13	25.039	12.38	12.38	12.38	12.37	12.36	12.36	Y	5.4669	pass
14	24.997	12.37	12.37	12.37	12.36	12.36	12.36	Y	5.4797	fail
15	25.030	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4835	pass
16	25.016	12.36	12.36	12.37	12.36	12.35	12.35	Y	5.4879	fail
17	25.074	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4861	pass
18	24.960	12.37	12.37	12.38	12.37	12.36	12.36	Y	5.4730	fail
19	25.256	12.36	12.37	12.36	12.36	12.35	12.35	Y	5.4874	pass
20	25.003	12.38	12.38	12.38	12.38	12.37	12.37	Y	5.4855	fail
21	25.017	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4967	fail
22	25.053	12.38	12.37	12.37	12.38	12.36	12.37	Y	5.4980	pass
23	24.994	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4814	fail
24	25.022	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4810	pass
25	25.012	12.36	12.37	12.36	12.37	12.35	12.35	Y	5.4664	fail
26	25.008	12.38	12.38	12.37	12.37	12.36	12.36	Y	5.4725	fail
27	24.992	12.38	12.38	12.38	12.38	12.36	12.36	Y	5.4936	fail
28	25.125	12.37	12.36	12.37	12.37	12.36	12.36	Y	5.4878	pass
29	25.114	12.38	12.38	12.38	12.38	12.37	12.36	Y	5.4826	pass
30	25.115	12.37	12.36	12.37	12.37	12.35	12.36	Y	5.4756	pass
31	25.026	12.37	12.37	12.38	12.37	12.37	12.36	Y	5.4800	pass
32	25.005	12.37	12.37	12.37	12.37	12.37	12.36	Y	5.4732	fail
33	25.109	12.37	12.37	12.37	12.37	12.37	12.36	Y	5.5023	pass
34	25.097	12.37	12.36	12.37	12.36	12.36	12.36	Y	5.4893	pass
35	25.044	12.37	12.36	12.37	12.37	12.36	12.36	Y	5.4941	pass
36	25.031	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4655	pass
37	24.938	12.38	12.37	12.37	12.37	12.36	12.36	Y	5.4757	fail
38	24.941	12.37	12.37	12.38	12.38	12.37	12.38	Y	5.4797	fail
39	25.147	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.5035	pass
40	25.073	12.37	12.37	12.38	12.38	12.37	12.36	Y	5.4913	pass

Comments

Page 1 of 2
For diameter measurement, top corresponds to compact end at top during pressing.
Top end cap appears shinier than bottom.

Operator

5-9-06
Date

QC Supervisor

5-3-06
Date

QA Reviewer

5/11/06
Date

Data Report Form DRF-24: Compact Diameter and Length

Procedure:	AGR-CHAR-DAM-24 Rev. 3
Operator:	Ivan Dunbar
Compact lot ID:	LEU01-46T-Z
Compact Lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T
Filename:	\\mc-agr\AGR\CompactDimensions\LEU01-46T-Z_DRF24R3.xls

Vertical height gauge calibration due date:	9/8/06
Pass-thru block calibration due date:	1/17/09
Digital caliper calibration due date:	9/8/06
Gauge blocks calibration due date:	9/8/06

Acceptance criteria for compact length:	≥25.02 and ≤25.40 mm
Acceptance criteria for compact diameter:	≥12.22 and ≤12.46 mm (and pass through 12.46 mm ring gauge)
Acceptance criteria for compact mass:	For information only

Compact ID Number	Length (mm)	Diameter (mm)						Pass Thru? (Y or N)	Mass (g)	Accept? (pass or fail)
		Top 1	Top 2	Middle 1	Middle 2	Bottom 1	Bottom 2			
41	25.052	12.38	12.38	12.38	12.37	12.36	12.36	Y	5.4934	pass
42	25.059	12.37	12.37	12.36	12.36	12.35	12.36	Y	5.4867	pass
43	25.133	12.37	12.36	12.36	12.37	12.36	12.36	Y	5.4941	pass
44	25.027	12.37	12.37	12.36	12.37	12.37	12.36	Y	5.4851	pass
45	25.077	12.36	12.36	12.36	12.36	12.36	12.36	Y	5.4670	pass
46	25.074	12.36	12.36	12.36	12.36	12.35	12.35	Y	5.4631	pass
47	25.041	12.37	12.37	12.37	12.37	12.37	12.37	Y	5.4802	pass
48	25.046	12.37	12.37	12.37	12.37	12.36	12.37	Y	5.4875	pass
49	25.090	12.37	12.37	12.37	12.37	12.37	12.36	Y	5.4791	pass
50	25.140	12.37	12.37	12.37	12.37	12.36	12.35	Y	5.4843	pass
51	25.086	12.36	12.36	12.37	12.36	12.36	12.35	Y	5.4649	pass
52	25.143	12.36	12.36	12.36	12.36	12.36	12.35	Y	5.4792	pass
53	25.022	12.37	12.37	12.37	12.37	12.37	12.36	Y	5.4877	pass
54	25.046	12.37	12.37	12.37	12.36	12.36	12.35	Y	5.4938	pass
55	25.065	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4907	pass
56	25.073	12.37	12.36	12.37	12.37	12.36	12.37	Y	5.4913	pass
57	25.142	12.36	12.36	12.37	12.37	12.35	12.35	Y	5.4829	pass
58	25.073	12.36	12.36	12.36	12.36	12.35	12.35	Y	5.4760	pass
59	25.055	12.36	12.36	12.37	12.36	12.36	12.35	Y	5.4883	pass
60	25.250	12.36	12.36	12.36	12.36	12.36	12.35	Y	5.4757	pass
61	25.015	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4877	fail
62	25.135	12.36	12.36	12.36	12.36	12.35	12.35	Y	5.4719	pass
63	24.997	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4895	fail
64	25.045	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.5164	pass
65	25.032	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4856	pass
66	24.977	12.36	12.37	12.36	12.37	12.36	12.36	Y	5.4737	fail
67	25.001	12.36	12.36	12.36	12.36	12.35	12.36	Y	5.4546	fail
68	24.928	12.37	12.36	12.37	12.37	12.36	12.36	Y	5.4756	fail
69	25.036	12.37	12.37	12.37	12.37	12.35	12.36	Y	5.4695	pass
70	25.024	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4930	pass
71	25.041	12.36	12.37	12.36	12.37	12.35	12.35	Y	5.5056	pass
72	25.012	12.37	12.36	12.36	12.37	12.36	12.36	Y	5.4745	fail
73	25.262	12.36	12.36	12.36	12.37	12.35	12.36	Y	5.4795	pass
74	24.996	12.37	12.37	12.38	12.38	12.36	12.36	Y	5.4793	fail
75	25.030	12.36	12.37	12.37	12.37	12.36	12.36	Y	5.4941	pass
76	24.942	12.37	12.37	12.37	12.37	12.36	12.37	Y	5.4706	fail
77	24.997	12.36	12.37	12.37	12.37	12.36	12.36	Y	5.4648	fail
78	24.960	12.36	12.36	12.36	12.37	12.36	12.36	Y	5.4374	fail
79	24.985	12.37	12.37	12.37	12.37	12.36	12.36	Y	5.4721	fail

Comments

Page 2 of 2
For diameter measurement, top corresponds to compact end at top during pressing.
Top end cap appears shinier than bottom.

Operator — 3-9-06 — Date

QC Supervisor — 5-3-06 — Date

QA Reviewer — 5/11/06 — Date

Data Report Form DRF-25: Fuel Compact Mean Uranium Loading

Procedure:	AGR-CHAR-DAM-25 Rev. 1
Operator:	Montgomery
Compact lot ID:	LEU01-46T-Z
Compact lot description:	Compacts of AGR-1 baselilne coated particle composite LEU01-46T
Filename:	\\mc-agr\AGR\UraniumLoading\LEU01-46T-Z_DRF25R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Compact ID number:	1	16	21	45	71	72
Sample tube ID number:	U06031301	U06031302	U06031303	U06031304	U06031305	U06031306
Radiochemical laboratory analysis number:	060315-031	060315-032	060315-033	060315-034	060315-035	060315-036
Measured U in compact (g):	0.92164	0.92012	0.92043	0.90734	0.91301	0.91697
Uncertainty in measured U in compact (g):	0.00092	0.00092	0.00092	0.00091	0.00091	0.00092

Mean uranium loading (gU/compact):	0.917
Standard deviation in mean uranium loading (gU/compact):	0.005

Comments
Four additional Davies-Gray analyses were performed on sample 1, grams U in compact: 0.92057, 0.92209, 0.92177, 0.92167. Mean of five measurements on sample 1: 0.9215 g, Standard error in mean: 0.0003 g. Data checked against official analysis results 5/3/06.

Fred C. Montgomery
Operator

5/3/06
Date

Data Report Form DRF-26A: Measurement of U Contamination and Impurities by Deconsolidation Leach

Procedure:	AGR-CHAR-DAM-26 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T
Compact ID numbers:	10, 13, 66
DRF filename:	\\mc-agr\AGR\LeachBurnLeach\LEU01-46T-Z_DRF26R0.xls

Mean average weight/kernel (g):	2.42E-04
Uncertainty in mean average weight/kernel (g):	5.96E-07
Mean weight % uranium/kernel:	90.06
Standard deviation in weight % uranium/kernel:	0.09
Approximate weight uranium/kernel (g):	2.18E-04
Uncertainty in approx. weight uranium/kernel (g):	5.76E-07

	First Leach	Second Leach	Total
Deconsolidation-leach solution ID:	L0603170201	L0603200202	
Number of compacts:	3		
Volume of leach solution (ml):			
Measured β activity of 0.1ml aliquot (dpm):			
Estimated weight of U in leach solution (mg):			
Radiochemical laboratory analysis number:	060406-019	060406-022	
Weight uranium leached (g):	4.50E-07	4.41E-08	4.94E-07
Uncertainty in weight uranium leached (g):	4.50E-08	4.40E-09	4.52E-08
Effective number of exposed kernels:	0.0	0.0	0.0
Uncertainty in effective number of exposed kernels:	0.0	0.0	0.0
Fe content of leach solution (µg):	3.60	1.55	5.15
Uncertainty in measured Fe content (µg):	0.36	0.31	0.48
Cr content of leach solution (µg):	< 1.59	< 1.77	3.36
Uncertainty in measured Cr content (µg):			
Mn content of leach solution (µg):	< 0.23	0.63	0.85
Uncertainty in measured Mn content (µg):		0.13	0.13
Co content of leach solution (µg):	< 0.63	< 0.71	1.34
Uncertainty in measured Co content (µg):			
Ni content of leach solution (µg):	< 1.13	< 1.25	2.38
Uncertainty in measured Ni content (µg):			
Ca content of leach solution (µg):	17.20	6.75	23.95
Uncertainty in measured Ca content (µg):	1.70	1.40	2.20
Al content of leach solution (µg):	11.50	8.03	19.53
Uncertainty in measured Al content (µg):	2.30	1.60	2.80
Ti content of leach solution (µg):	8.03	8.98	17.01
Uncertainty in measured Ti content (µg):	1.60	1.80	2.41
V content of leach solution (µg):	23.70	5.90	29.60
Uncertainty in measured V content (µg):	2.40	0.59	2.47

Comments

Data checked against official analysis results IPA14213 on 5/2/06

Fred C. Montgomery
Operator

5/2/06
Date

Data Report Form DRF-26A: Measurement of U Contamination and Impurities by Deconsolidation Leach

Procedure:	AGR-CHAR-DAM-26 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T
Compact ID numbers:	40, 48, 64
DRF filename:	\\mc-agr\AGR\LeachBurnLeach\LEU01-46T-Z_DRF26R0.xls

Mean average weight/kernel (g):	2.42E-04
Uncertainty in mean average weight/kernel (g):	5.96E-07
Mean weight % uranium/kernel:	90.06
Standard deviation in weight % uranium/kernel:	0.09
Approximate weight uranium/kernel (g):	2.18E-04
Uncertainty in approx. weight uranium/kernel (g):	5.76E-07

	First Leach	Second Leach	Total
Deconsolidation-leach solution ID:	L0603170301	L0603200302	
Number of compacts:	3		
Volume of leach solution (ml):			
Measured β activity of 0.1ml aliquot (dpm):			
Estimated weight of U in leach solution (mg):			
Radiochemical laboratory analysis number:	060406-020	060406-023	
Weight uranium leached (g):	7.00E-07	9.46E-08	7.95E-07
Uncertainty in weight uranium leached (g):	7.00E-08	9.50E-09	7.06E-08
Effective number of exposed kernels:	0.0	0.0	0.0
Uncertainty in effective number of exposed kernels:	0.0	0.0	0.0
Fe content of leach solution (μg):	4.41	1.45	5.86
Uncertainty in measured Fe content (μg):	0.44	0.29	0.53
Cr content of leach solution (μg):	< 1.58	< 1.80	3.38
Uncertainty in measured Cr content (μg):			
Mn content of leach solution (μg):	< 0.23	0.64	0.86
Uncertainty in measured Mn content (μg):		0.13	0.13
Co content of leach solution (μg):	< 0.63	< 0.72	1.35
Uncertainty in measured Co content (μg):			
Ni content of leach solution (μg):	< 1.12	< 1.28	2.40
Uncertainty in measured Ni content (μg):			
Ca content of leach solution (μg):	14.90	6.99	21.89
Uncertainty in measured Ca content (μg):	1.50	1.40	2.05
Al content of leach solution (μg):	9.90	8.26	18.16
Uncertainty in measured Al content (μg):	2.00	1.70	2.62
Ti content of leach solution (μg):	6.32	8.26	14.58
Uncertainty in measured Ti content (μg):	1.30	1.70	2.14
V content of leach solution (μg):	23.30	5.13	28.43
Uncertainty in measured V content (μg):	2.30	0.51	2.36

Comments

Data checked against official analysis results IPA14213 on 5/2/06

Fred C. Montgomery
Operator

5/2/06
Date

Data Report Form DRF-26A: Measurement of U Contamination and Impurities by Deconsolidation Leach

Procedure:	AGR-CHAR-DAM-26 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T
Compact ID numbers:	35, 54, 59
DRF filename:	\\mc-agr\AGR\LeachBurnLeach\LEU01-46T-Z_DRF26R0.xls

Mean average weight/kernel (g):	2.42E-04
Uncertainty in mean average weight/kernel (g):	5.96E-07
Mean weight % uranium/kernel:	90.06
Standard deviation in weight % uranium/kernel:	0.09
Approximate weight uranium/kernel (g):	2.18E-04
Uncertainty in approx. weight uranium/kernel (g):	5.76E-07

	First Leach	Second Leach	Total
Deconsolidation-leach solution ID:	L0603210101	L0603230102	
Number of compacts:	3		
Volume of leach solution (ml):			
Measured β activity of 0.1ml aliquot (dpm):			
Estimated weight of U in leach solution (mg):			
Radiochemical laboratory analysis number:	060406-024	060406-028	
Weight uranium leached (g):	1.07E-08	7.66E-08	8.73E-08
Uncertainty in weight uranium leached (g):	1.10E-09	7.70E-09	7.78E-09
Effective number of exposed kernels:	0.0	0.0	0.0
Uncertainty in effective number of exposed kernels:	0.0	0.0	0.0
Fe content of leach solution (µg):	3.02	5.85	8.87
Uncertainty in measured Fe content (µg):	0.30	0.59	0.66
Cr content of leach solution (µg):	< 1.59	< 1.77	3.36
Uncertainty in measured Cr content (µg):			
Mn content of leach solution (µg):	0.59	0.60	1.19
Uncertainty in measured Mn content (µg):	0.12	0.12	0.17
Co content of leach solution (µg):	< 0.63	< 0.71	1.34
Uncertainty in measured Co content (µg):			
Ni content of leach solution (µg):	< 1.13	< 1.25	2.38
Uncertainty in measured Ni content (µg):			
Ca content of leach solution (µg):	15.20	3.48	18.68
Uncertainty in measured Ca content (µg):	1.50	0.70	1.66
Al content of leach solution (µg):	9.14	< 6.82	15.96
Uncertainty in measured Al content (µg):	1.80		1.80
Ti content of leach solution (µg):	6.55	8.35	14.90
Uncertainty in measured Ti content (µg):	1.30	1.70	2.14
V content of leach solution (µg):	24.40	6.58	30.98
Uncertainty in measured V content (µg):	2.40	0.66	2.49

Comments

Data checked against official analysis results IPA14213 on 5/2/06

Fred C. Montgomery
Operator

5/2/06
Date

Data Report Form DRF-26A: Measurement of U Contamination and Impurities by Deconsolidation Leach

Procedure:	AGR-CHAR-DAM-26 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T
Compact ID numbers:	08, 26, 75
DRF filename:	\\mc-agr\AGR\LeachBurnLeach\LEU01-46T-Z_DRF26R0.xls

Mean average weight/kernel (g):	2.42E-04
Uncertainty in mean average weight/kernel (g):	5.96E-07
Mean weight % uranium/kernel:	90.06
Standard deviation in weight % uranium/kernel:	0.09
Approximate weight uranium/kernel (g):	2.18E-04
Uncertainty in approx. weight uranium/kernel (g):	5.76E-07

	First Leach	Second Leach	Total
Deconsolidation-leach solution ID:	L0603210201	L0603230202	
Number of compacts:	3		
Volume of leach solution (ml):			
Measured β activity of 0.1ml aliquot (dpm):			
Estimated weight of U in leach solution (mg):			
Radiochemical laboratory analysis number:	060406-025	060406-029	
Weight uranium leached (g):	6.36E-07	5.22E-08	6.88E-07
Uncertainty in weight uranium leached (g):	6.40E-08	5.20E-09	6.42E-08
Effective number of exposed kernels:	0.0	0.0	0.0
Uncertainty in effective number of exposed kernels:	0.0	0.0	0.0
Fe content of leach solution (µg):	2.67	2.18	4.85
Uncertainty in measured Fe content (µg):	0.53	0.44	0.69
Cr content of leach solution (µg):	< 1.52	< 1.70	3.22
Uncertainty in measured Cr content (µg):			
Mn content of leach solution (µg):	0.54	0.58	1.11
Uncertainty in measured Mn content (µg):	0.11	0.12	0.16
Co content of leach solution (µg):	< 0.61	< 0.68	1.28
Uncertainty in measured Co content (µg):			
Ni content of leach solution (µg):	< 1.08	< 1.20	2.28
Uncertainty in measured Ni content (µg):			
Ca content of leach solution (µg):	22.60	8.28	30.88
Uncertainty in measured Ca content (µg):	2.30	1.70	2.86
Al content of leach solution (µg):	16.50	10.50	27.00
Uncertainty in measured Al content (µg):	3.30	2.10	3.91
Ti content of leach solution (µg):	5.40	8.06	13.46
Uncertainty in measured Ti content (µg):	1.10	1.60	1.94
V content of leach solution (µg):	23.30	6.96	30.26
Uncertainty in measured V content (µg):	2.30	0.70	2.40

Comments

Data checked against official analysis results IPA14213 on 5/2/06

Fred C. Montgomery
Operator

5/02/06
Date

Data Report Form DRF-26A: Measurement of U Contamination and Impurities by Deconsolidation Leach

Procedure:	AGR-CHAR-DAM-26 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T
Compact ID numbers:	02, 04, 11, 28, 31, 61
DRF filename:	\\mc-agr\AGR\LeachBurnLeach\LEU01-46T-Z_DRF26R0.xls

Mean average weight/kernel (g):	2.42E-04
Uncertainty in mean average weight/kernel (g):	5.96E-07
Mean weight % uranium/kernel:	90.06
Standard deviation in weight % uranium/kernel:	0.09
Approximate weight uranium/kernel (g):	2.18E-04
Uncertainty in approx. weight uranium/kernel (g):	5.76E-07

	First Leach	Second Leach	Total
Deconsolidation-leach solution ID:	L0603220101	L0603250102	
Number of compacts:	6		
Volume of leach solution (ml):			
Measured β activity of 0.1ml aliquot (dpm):			
Estimated weight of U in leach solution (mg):			
Radiochemical laboratory analysis number:	060406-027	060406-031	
Weight uranium leached (g):	4.44E-06	2.43E-07	4.68E-06
Uncertainty in weight uranium leached (g):	4.40E-07	2.40E-08	4.41E-07
Effective number of exposed kernels:	0.0	0.0	0.0
Uncertainty in effective number of exposed kernels:	0.0	0.0	0.0
Fe content of leach solution (µg):	3.46	2.18	5.64
Uncertainty in measured Fe content (µg):	0.69	0.44	0.82
Cr content of leach solution (µg):	< 2.69	< 2.37	5.06
Uncertainty in measured Cr content (µg):			
Mn content of leach solution (µg):	0.95	0.84	1.79
Uncertainty in measured Mn content (µg):	0.19	0.17	0.25
Co content of leach solution (µg):	< 1.07	< 0.95	2.02
Uncertainty in measured Co content (µg):			
Ni content of leach solution (µg):	< 1.90	< 1.68	3.58
Uncertainty in measured Ni content (µg):			
Ca content of leach solution (µg):	28.90	5.53	34.43
Uncertainty in measured Ca content (µg):	2.90	1.10	3.10
Al content of leach solution (µg):	14.60	11.30	25.90
Uncertainty in measured Al content (µg):	2.90	2.30	3.70
Ti content of leach solution (µg):	18.10	18.30	36.40
Uncertainty in measured Ti content (µg):	1.80	1.80	2.55
V content of leach solution (µg):	47.70	10.00	57.70
Uncertainty in measured V content (µg):	4.80	1.00	4.90

Comments

Data checked against official analysis results IPA14213 on 5/2/06

Fred C. Montgomery
Operator

5/02/06
Date

Data Report Form DRF-26A: Measurement of U Contamination and Impurities by Deconsolidation Leach

Procedure:	AGR-CHAR-DAM-26 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T
Compact ID numbers:	25, 41, 51, 63, 70, 73
DRF filename:	\\mc-agr\AGR\LeachBurnLeach\LEU01-46T-Z_DRF26R0.xls

Mean average weight/kernel (g):	2.42E-04
Uncertainty in mean average weight/kernel (g):	5.96E-07
Mean weight % uranium/kernel:	90.06
Standard deviation in weight % uranium/kernel:	0.09
Approximate weight uranium/kernel (g):	2.18E-04
Uncertainty in approx. weight uranium/kernel (g):	5.76E-07

	First Leach	Second Leach	Total
Deconsolidation-leach solution ID:	L0603250201	L0603280102	
Number of compacts:	6		
Volume of leach solution (ml):			
Measured β activity of 0.1ml aliquot (dpm):			
Estimated weight of U in leach solution (mg):			
Radiochemical laboratory analysis number:	060406-032	060406-033	
Weight uranium leached (g):	1.17E-06	1.00E-07	1.27E-06
Uncertainty in weight uranium leached (g):	1.20E-07	1.00E-08	1.20E-07
Effective number of exposed kernels:	0.0	0.0	0.0
Uncertainty in effective number of exposed kernels:	0.0	0.0	0.0
Fe content of leach solution (µg):	16.70	3.99	20.69
Uncertainty in measured Fe content (µg):	1.70	0.80	1.88
Cr content of leach solution (µg):	< 2.12	< 2.37	4.49
Uncertainty in measured Cr content (µg):			
Mn content of leach solution (µg):	0.81	0.84	1.65
Uncertainty in measured Mn content (µg):	0.16	0.17	0.23
Co content of leach solution (µg):	< 0.85	< 0.95	1.79
Uncertainty in measured Co content (µg):			
Ni content of leach solution (µg):	< 1.50	< 1.68	3.18
Uncertainty in measured Ni content (µg):			
Ca content of leach solution (µg):	20.10	5.09	25.19
Uncertainty in measured Ca content (µg):	2.00	1.00	2.24
Al content of leach solution (µg):	< 8.18	13.40	21.58
Uncertainty in measured Al content (µg):		2.70	2.70
Ti content of leach solution (µg):	11.70	12.80	24.50
Uncertainty in measured Ti content (µg):	2.30	2.60	3.47
V content of leach solution (µg):	45.90	10.80	56.70
Uncertainty in measured V content (µg):	4.60	1.10	4.73

Comments

Data checked against official analysis results IPA14213 on 5/2/06

Fred C. Montgomery
Operator

5/02/06
Date

Data Report Form DRF-26B: Measurement of SiC Burn-Leach Defects and Impurities by Burn-Leach

Procedure:	AGR-CHAR-DAM-26 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T
Compact ID numbers:	10, 13, 66
DRF filename:	\\mc-agr\AGR\LeachBurnLeach\LEU01-46T-Z_DRF26R0.xls

Mean average weight/kernel (g):	2.42E-04
Uncertainty in mean average weight/kernel (g):	5.96E-07
Mean weight % uranium/kernel:	90.06
Standard deviation in weight % uranium/kernel:	0.09
Approximate weight uranium/kernel (g):	2.18E-04
Uncertainty in approx. weight uranium/kernel (g):	5.76E-07

	First Leach	Second Leach	Total
Burn-leach solution ID:	B0603280201	B0603300202	
Number of compacts:	3		
Volume of leach solution (ml):			
Measured β activity of 0.1ml aliquot (dpm):			
Estimated weight of U in leach solution (mg):			
Radiochemical laboratory analysis number:	060406-002	060406-005	
Weight uranium leached (g):	2.29E-04	3.86E-07	2.29E-04
Uncertainty in weight uranium leached (g):	2.30E-05	3.90E-08	2.30E-05
Number of leached kernels:	1.1	0.0	1.1
Uncertainty in number of leached kernels:	0.1	0.0	0.1
Fe content of leach solution (µg):	1.63	< 0.26	1.89
Uncertainty in measured Fe content (µg):	0.16		0.16
Cr content of leach solution (µg):	< 0.71	< 0.71	1.41
Uncertainty in measured Cr content (µg):			
Mn content of leach solution (µg):	< 0.10	< 0.10	0.20
Uncertainty in measured Mn content (µg):			
Co content of leach solution (µg):	< 0.28	< 0.28	0.56
Uncertainty in measured Co content (µg):			
Ni content of leach solution (µg):	< 0.50	< 0.50	1.00
Uncertainty in measured Ni content (µg):			
Ca content of leach solution (µg):	11.00	3.11	14.11
Uncertainty in measured Ca content (µg):	1.10	0.62	1.26
Al content of leach solution (µg):	11.40	< 2.73	14.13
Uncertainty in measured Al content (µg):	2.30		2.30
Ti content of leach solution (µg):	1.36	3.60	4.96
Uncertainty in measured Ti content (µg):	0.27	0.72	0.77
V content of leach solution (µg):	20.80	1.71	22.51
Uncertainty in measured V content (µg):	2.10	0.34	2.13

Comments

Data checked against official analysis results IPA14213 on 5/2/06

Fred C. Montgomery
Operator

5-02-06
Date

Data Report Form DRF-26B: Measurement of SiC Burn-Leach Defects and Impurities by Burn-Leach

Procedure:	AGR-CHAR-DAM-26 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T
Compact ID numbers:	40, 48, 64
DRF filename:	\\mc-agr\AGR\LeachBurnLeach\LEU01-46T-Z_DRF26R0.xls

Mean average weight/kernel (g):	2.42E-04
Uncertainty in mean average weight/kernel (g):	5.96E-07
Mean weight % uranium/kernel:	90.06
Standard deviation in weight % uranium/kernel:	0.09
Approximate weight uranium/kernel (g):	2.18E-04
Uncertainty in approx. weight uranium/kernel (g):	5.76E-07

	First Leach	Second Leach	Total
Burn-leach solution ID:	B0603280301	B0603300302	
Number of compacts:	3		
Volume of leach solution (ml):			
Measured β activity of 0.1ml aliquot (dpm):			
Estimated weight of U in leach solution (mg):			
Radiochemical laboratory analysis number:	060406-003	060406-006	
Weight uranium leached (g):	2.47E-04	1.27E-07	2.47E-04
Uncertainty in weight uranium leached (g):	2.50E-05	1.30E-08	2.50E-05
Number of leached kernels:	1.1	0.0	1.1
Uncertainty in number of leached kernels:	0.1	0.0	0.1
Fe content of leach solution (µg):	1.82	< 0.26	2.08
Uncertainty in measured Fe content (µg):	0.18		0.18
Cr content of leach solution (µg):	< 0.71	< 0.71	1.41
Uncertainty in measured Cr content (µg):			
Mn content of leach solution (µg):	< 0.10	< 0.10	0.20
Uncertainty in measured Mn content (µg):			
Co content of leach solution (µg):	< 0.28	< 0.28	0.56
Uncertainty in measured Co content (µg):			
Ni content of leach solution (µg):	0.76	< 0.50	1.26
Uncertainty in measured Ni content (µg):	0.15		0.15
Ca content of leach solution (µg):	22.10	4.85	26.95
Uncertainty in measured Ca content (µg):	2.20	0.97	2.40
Al content of leach solution (µg):	12.10	< 2.73	14.83
Uncertainty in measured Al content (µg):	2.40		2.40
Ti content of leach solution (µg):	11.90	< 0.86	12.76
Uncertainty in measured Ti content (µg):	1.20		1.20
V content of leach solution (µg):	20.10	1.32	21.42
Uncertainty in measured V content (µg):	2.00	0.26	2.02

Comments

Data checked against official analysis results IPA14213 on 5/2/06

Fred C. Montgomery
Operator

5/04/06
Date

Data Report Form DRF-26B: Measurement of SiC Burn-Leach Defects and Impurities by Burn-Leach

Procedure:	AGR-CHAR-DAM-26 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T
Compact ID numbers:	35, 54, 59
DRF filename:	\\mc-agr\AGR\LeachBurnLeach\LEU01-46T-Z_DRF26R0.xls

Mean average weight/kernel (g):	2.42E-04
Uncertainty in mean average weight/kernel (g):	5.96E-07
Mean weight % uranium/kernel:	90.06
Standard deviation in weight % uranium/kernel:	0.09
Approximate weight uranium/kernel (g):	2.18E-04
Uncertainty in approx. weight uranium/kernel (g):	5.76E-07

	First Leach	Second Leach	Total
Burn-leach solution ID:	B0603310101	B0604030302	
Number of compacts:	3		
Volume of leach solution (ml):			
Measured β activity of 0.1ml aliquot (dpm):			
Estimated weight of U in leach solution (mg):			
Radiochemical laboratory analysis number:	060406-007	060406-013	
Weight uranium leached (g):	2.14E-07	6.70E-09	2.21E-07
Uncertainty in weight uranium leached (g):	2.10E-08	6.70E-10	2.10E-08
Number of leached kernels:	0.0	0.0	0.0
Uncertainty in number of leached kernels:	0.0	0.0	0.0
Fe content of leach solution (µg):	1.20	< 0.26	1.46
Uncertainty in measured Fe content (µg):	0.22		0.22
Cr content of leach solution (µg):	< 0.71	< 0.71	1.41
Uncertainty in measured Cr content (µg):			
Mn content of leach solution (µg):	< 0.10	0.27	0.37
Uncertainty in measured Mn content (µg):		0.05	0.05
Co content of leach solution (µg):	< 0.28	< 0.28	0.56
Uncertainty in measured Co content (µg):			
Ni content of leach solution (µg):	1.16	< 0.50	1.66
Uncertainty in measured Ni content (µg):	0.23		0.23
Ca content of leach solution (µg):	20.80	1.32	22.12
Uncertainty in measured Ca content (µg):	2.10	0.26	2.12
Al content of leach solution (µg):	5.41	< 2.73	8.14
Uncertainty in measured Al content (µg):	1.10		1.10
Ti content of leach solution (µg):	10.80	3.29	14.09
Uncertainty in measured Ti content (µg):	1.10	0.66	1.28
V content of leach solution (µg):	26.60	0.94	27.54
Uncertainty in measured V content (µg):	2.70	0.19	2.71

Comments

Data checked against official analysis results IPA14213 on 5/2/06

Fred C. Montgomery
Operator

5/02/06
Date

Data Report Form DRF-26B: Measurement of SiC Burn-Leach Defects and Impurities by Burn-Leach

Procedure:	AGR-CHAR-DAM-26 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T
Compact ID numbers:	08, 26, 75
DRF filename:	\\mc-agr\AGR\LeachBurnLeach\LEU01-46T-Z_DRF26R0.xls

Mean average weight/kernel (g):	2.42E-04
Uncertainty in mean average weight/kernel (g):	5.96E-07
Mean weight % uranium/kernel:	90.06
Standard deviation in weight % uranium/kernel:	0.09
Approximate weight uranium/kernel (g):	2.18E-04
Uncertainty in approx. weight uranium/kernel (g):	5.76E-07

	First Leach	Second Leach	Total
Burn-leach solution ID:	B0603310201	B0604030402	
Number of compacts:	3		
Volume of leach solution (ml):			
Measured β activity of 0.1ml aliquot (dpm):			
Estimated weight of U in leach solution (mg):			
Radiochemical laboratory analysis number:	060406-008	060406-014	
Weight uranium leached (g):	3.97E-07	2.53E-08	4.22E-07
Uncertainty in weight uranium leached (g):	4.00E-08	2.50E-09	4.01E-08
Number of leached kernels:	0.0	0.0	0.0
Uncertainty in number of leached kernels:	0.0	0.0	0.0
Fe content of leach solution (µg):	4.15	1.32	5.47
Uncertainty in measured Fe content (µg):	0.42	0.13	0.44
Cr content of leach solution (µg):	< 0.71	< 0.71	1.41
Uncertainty in measured Cr content (µg):			
Mn content of leach solution (µg):	< 0.10	< 0.10	0.20
Uncertainty in measured Mn content (µg):			
Co content of leach solution (µg):	< 0.28	< 0.28	0.56
Uncertainty in measured Co content (µg):			
Ni content of leach solution (µg):	< 0.50	< 0.50	1.00
Uncertainty in measured Ni content (µg):			
Ca content of leach solution (µg):	15.40	3.22	18.62
Uncertainty in measured Ca content (µg):	1.50	0.64	1.63
Al content of leach solution (µg):	< 2.73	2.89	5.62
Uncertainty in measured Al content (µg):		0.58	0.58
Ti content of leach solution (µg):	8.88	7.38	16.26
Uncertainty in measured Ti content (µg):	0.89	0.74	1.16
V content of leach solution (µg):	26.40	1.20	27.60
Uncertainty in measured V content (µg):	2.60	0.24	2.61

Comments

Data checked against official analysis results IPA14213 on 5/2/06

Fred C. Montgomery
Operator

5/02/06
Date

Data Report Form DRF-27: Counting of Particles with a Defective OPyC Layer from Deconsolidated Compacts by Visual Inspection

Procedure:	AGR-CHAR-DAM-27 Rev. 0
Operator:	Fred Montgomery
Compact lot ID:	LEU01-46T-Z
Compact lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T
Compact ID number:	6
DRF filename:	\\mc-agr\AGR\DefectiveOPyC\LEU01-47T-Z_DRF27R0.xls

Number of particles with cracked OPyC:	0
Number of particles with partially missing OPyC:	0
Number of particles with completely missing OPyC:	0
Total number of particles with defective OPyC:	0

Comments on unusual visual characteristics of OPyC

<5 particles still had a thin layer of the matrix present. No agglomerates in the population.

Fred C. Montgomery — Operator

5/3/06 — Date

Data Report Form DRF-28: Counting of Particles with Excessive Uranium Dispersion Inside SiC

Procedure:	AGR-CHAR-DAM-28 Rev. 1
Operator:	John Hunn
Compact lot ID:	LEU01-46T-Z
Compact lot description:	Compacts of AGR-1 baseline coated particle composite LEU01-46T
Compact ID numbers:	10,13,66,40,48,64,35,54,59,08,26,75
DRF filename:	\\mc-agr\AGR\DefectiveIPyC\LEU01-46T-Z_DRF28R1.xls

Number of compacts from which particles were recovered:	12

Weight of sample of particles (g):	29.047
Number of particles in sample:	49735
Mean average weight/particle (g):	5.84E-04

Number of particles with excessive U dispersion:	0

Comments

No defects as defined by visual standard were observed. However a number of anomalies were noted.
Particles noted with <300 μm diameter kernel: 25/49735 (fraction of compact lot with this anomaly: ≤7.1E-4 at 95% confidence).
Particles noted with <20 μm thick SiC: 15/49735 (fraction of compact lot with this anomaly: ≤4.7E-4 at 95% confidence).
Other anomalies observed included highly aspherical kernel shapes, faceted particles, and defects related to goldspots (soot inclusions).

John Hunn — Operator

7-17-06 — Date

For Information Only

The information in the remainder of this section is from additional characterization that was not required by the fuel product specification.

A. Images of AGR-1 baseline compact lot LEU01-46T-Z

The compacting procedure allowed for some adjustment in the malleability of the overcoat to aid the compaction process, densify the compact, and create a smoother, less porous outer surface. Adjustments were made for the first five compacts fabricated to minimize the compact surface porosity. This resulted in some variation in the surface appearance of the first several compacts in compact lot LEU01-46T-Z. The following pictures show two compacts from lot LEU01-46T-Z. The compact shown in Figure A-1 through Figure A-3 was the fourth compact fabricated. This compact showed more gaps between the overcoated particles than compacts fabricated later, when adjustments had resulted in a smoother finish. The compact shown in Figure A-4 through Figure A-6 was the twenty sixth compact fabricated.

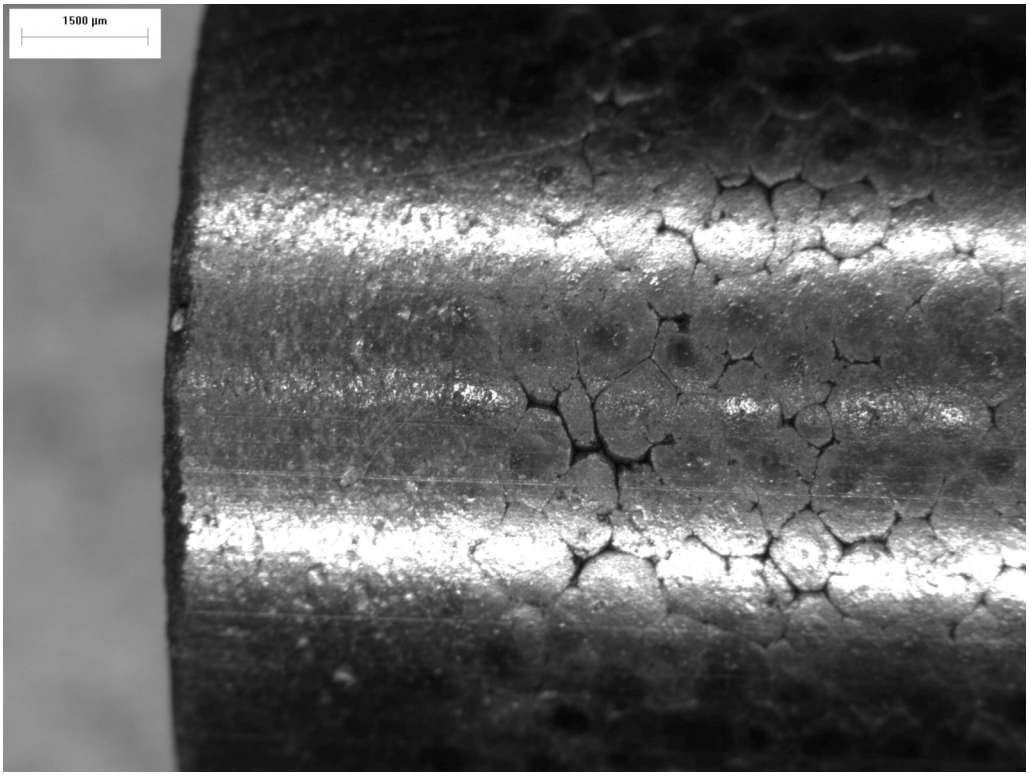


Figure A-1: Bottom of compact LEU01-46T-Z03 (4th compact fabricated).

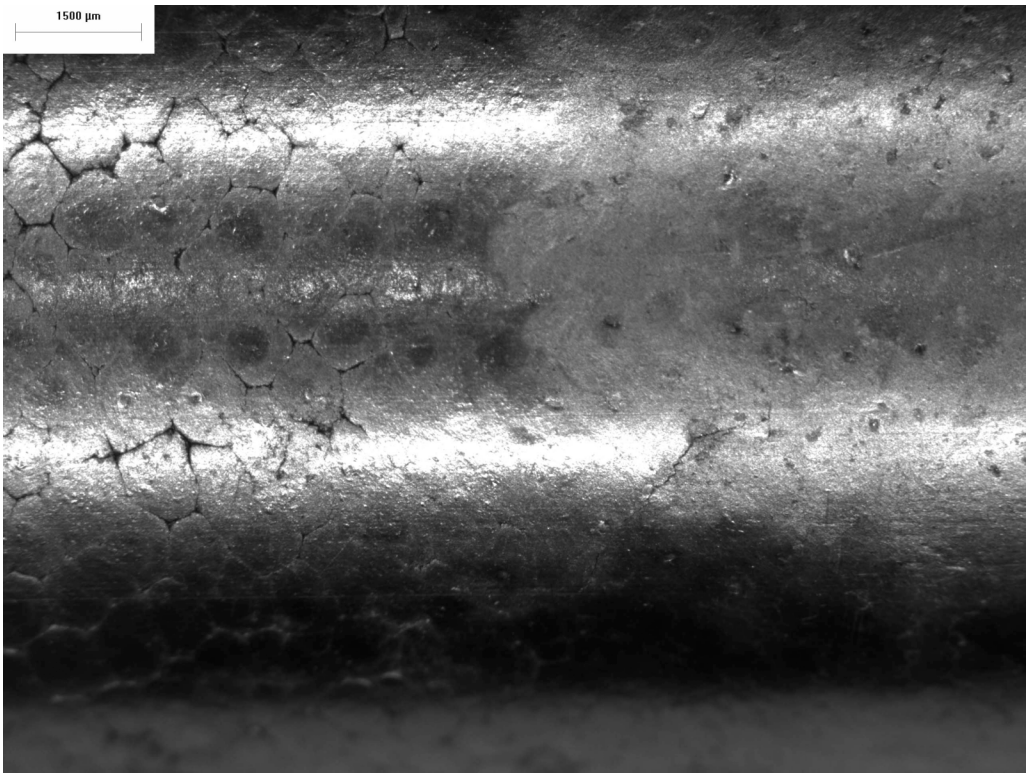


Figure A-2: Middle of compact LEU01-46T-Z03 (4th compact fabricated).

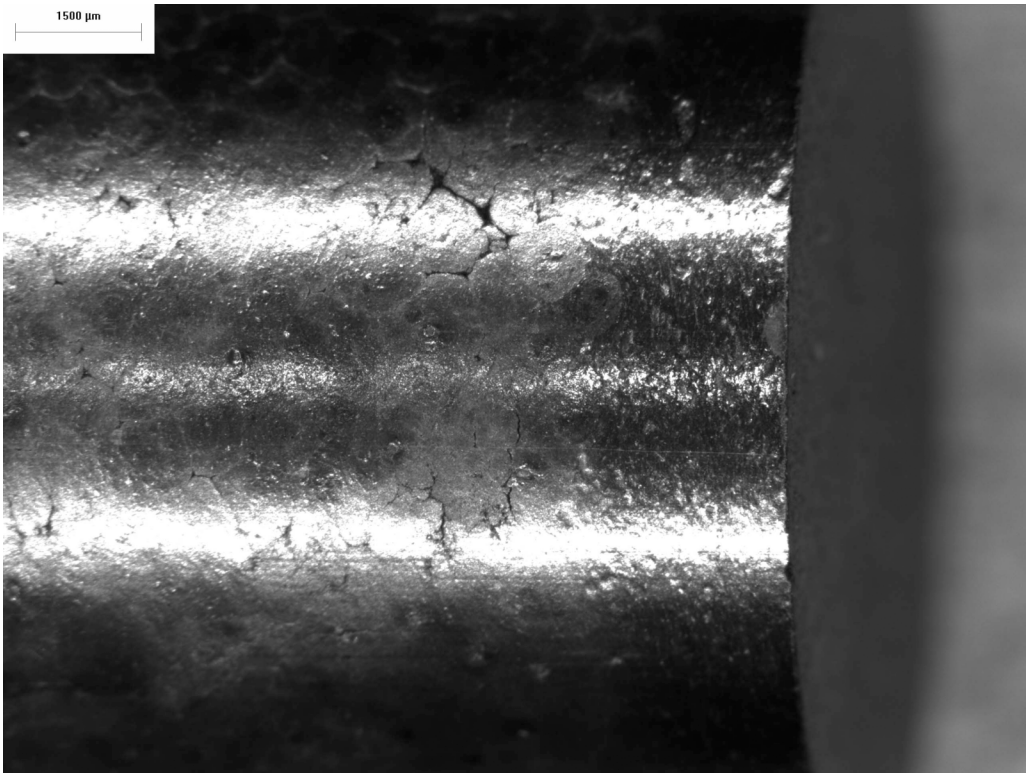


Figure A-3: Top of compact LEU01-46T-Z03 (4th compact fabricated).

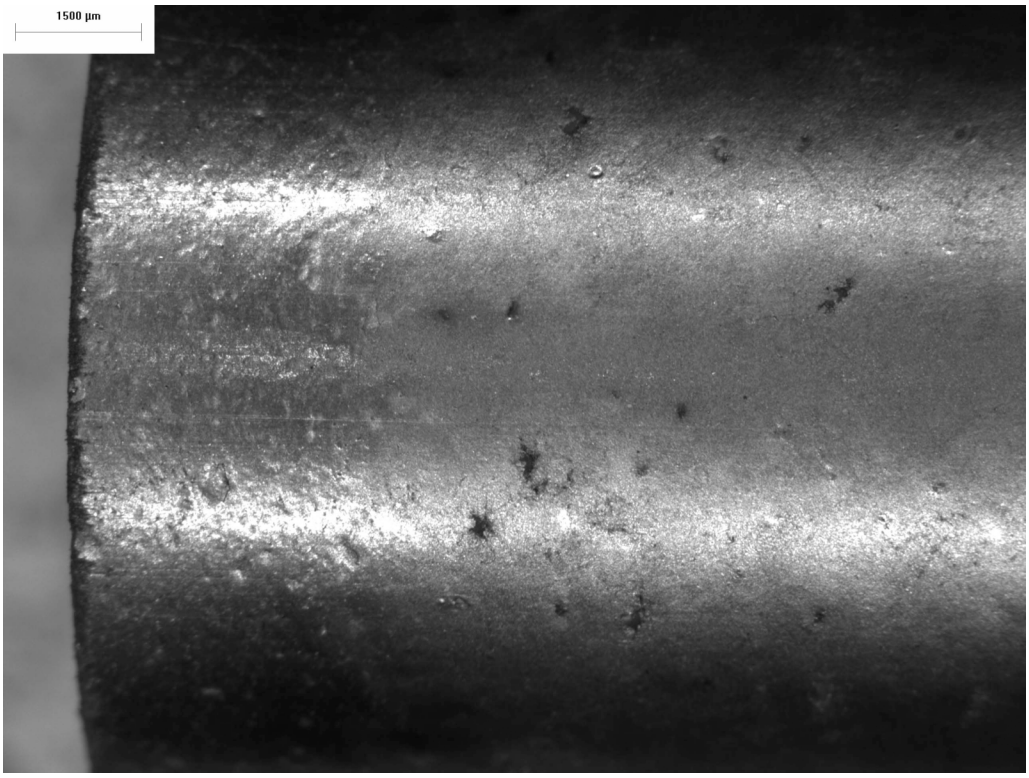


Figure A-4: Bottom of compact LEU01-46T-Z18 (26th compact fabricated).

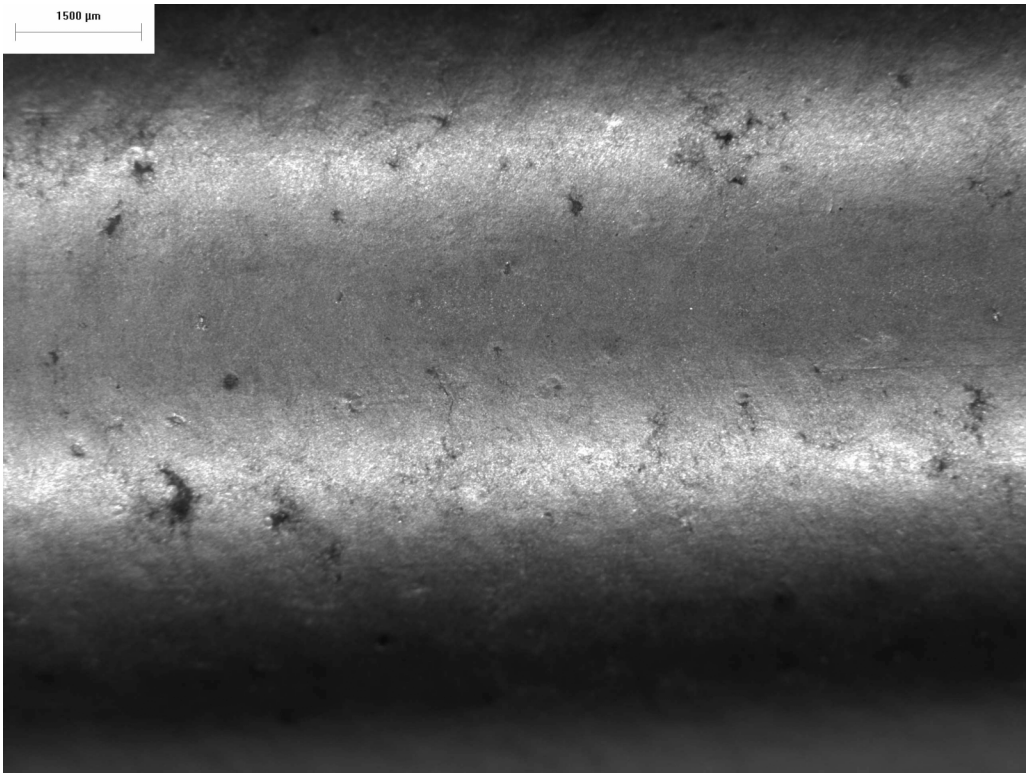


Figure A-5: Middle of compact LEU01-46T-Z18 (26th compact fabricated).

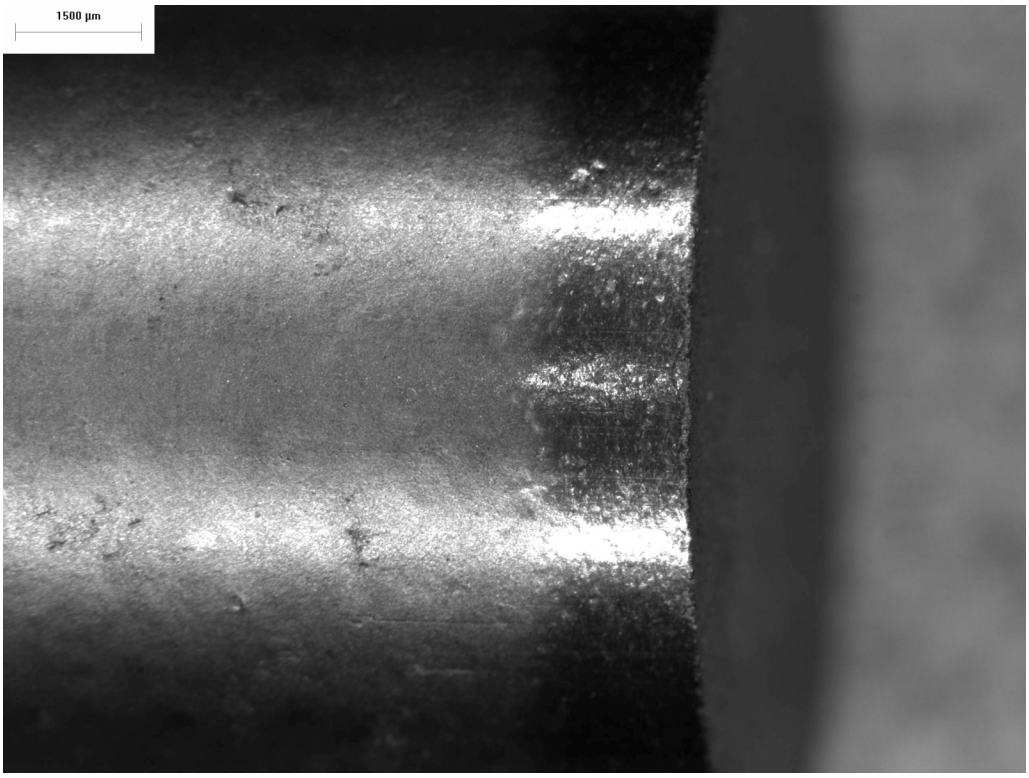


Figure A-6: Top of compact LEU01-46T-Z18 (26th compact fabricated).

B. Anisotropy of pyrocarbon layers after compacting

To examine the change in pyrocarbon anisotropy during compact fabrication, particles were recovered after deconsolidation of the particles from the compact for defective OPyC analysis. After compacting, the mean anisotropy of the pyrocarbon layers was observed to increase. This increase is thought to occur during the heat treatment of the compacts at 1800°C for 1 hour. The mean diattenuation of the IPyC increased from 0.0074±0.0007 to 0.0109±0.0013 (1.0222±0.0021 to 1.0326±0.0039 in terms of effective BAFo). The diattenuation of the OPyC increased from 0.0063±0.0009 to 0.0111±0.0009 (1.0190±0.0026 to 1.0334±0.0028 in terms of effective BAFo). The following two DRF's contain the data for these measurements.

Data Report Form DRF-18A: Measurement of Pyrocarbon Anisotropy using the 2-MGEM - IPyC

Procedure:	AGR-CHAR-DAM-18 Rev. 1
Operator:	G. E. Jellison
Mount ID:	M06062001L
Sample ID:	LEU01-46T-Z06
Sample Description:	Particles deconsolidated from AGR-1 baseline compact
Folder containing data:	\\mc-agr\AGR\2-MGEM\R06071401\

Particle #	Grid Position	Diattenuation			Equivalent BAFo		
		Average	St. Dev.	Ave. Error	Average	St. Dev.	Ave. Error
1	4,4	0.0122	0.0032	0.0012	1.0366	0.0096	0.0036
2	4,5	0.0104	0.0032	0.0012	1.0312	0.0096	0.0036
3	4,6	0.0108	0.0035	0.0012	1.0324	0.0105	0.0036
4	5,4	0.0088	0.0030	0.0012	1.0264	0.0090	0.0036
5	5,5	0.0127	0.0040	0.0013	1.0381	0.0120	0.0039
6	5,6	0.0097	0.0043	0.0013	1.0291	0.0129	0.0039
7	6,4	0.0126	0.0032	0.0013	1.0378	0.0096	0.0039
8	6,5	0.0112	0.0035	0.0013	1.0336	0.0105	0.0039
9	6,6	0.0100	0.0030	0.0013	1.0300	0.0090	0.0039
10	7,5	0.0102	0.0032	0.0013	1.0306	0.0096	0.0039
Average		0.0109	0.0034	0.0013	1.0326	0.0102	0.0038

Mean of average BAFo per particle:	1.0326
Standard deviation of average BAFo per particle:	0.0039

Comments

G. E. Jellison
Operator

July 14, 2006
Date

Data Report Form DRF-18B: Measurement of Pyrocarbon Anisotropy using the 2-MGEM - OPyC

Procedure:	AGR-CHAR-DAM-18 Rev. 1
Operator:	G. E. Jellison
Mount ID:	M06062001L
Sample ID:	LEU01-46T-Z06
Sample Description:	Particles deconsolidated from AGR-1 baseline compact
Folder containing data:	\\mc-agr\AGR\2-MGEM\R06071401\

Particle #	Grid Position	Diattenuation			Equivalent BAFo		
		Average	St. Dev.	Ave. Error	Average	St. Dev.	Ave. Error
1	4,4	0.0117	0.0028	0.0012	1.0351	0.0084	0.0036
2	4,5	0.0104	0.0033	0.0013	1.0312	0.0099	0.0039
3	4,6	0.0123	0.0038	0.0015	1.0369	0.0114	0.0045
4	5,4	0.0116	0.0031	0.0012	1.0348	0.0093	0.0036
5	5,5	0.0106	0.0033	0.0013	1.0318	0.0099	0.0039
6	5,6	0.0121	0.0042	0.0015	1.0363	0.0126	0.0045
7	6,4	0.0115	0.0037	0.0012	1.0345	0.0111	0.0036
8	6,5	0.0111	0.0034	0.0015	1.0333	0.0102	0.0045
9	6,6	0.0092	0.0032	0.0014	1.0276	0.0096	0.0042
10	7,5	0.0109	0.0034	0.0015	1.0327	0.0102	0.0045
Average		0.0111	0.0034	0.0014	1.0334	0.0103	0.0041

Mean of average BAFo per particle:	1.0334
Standard deviation of average BAFo per particle:	0.0028

Comments

G. E. Jellison — Operator

July 14, 2006 — Date

C. Defective IPyC analysis of LEU01-46T-Z compact lot

Particles recovered after leach-burn-leach of four sets of 3 compacts each were sandwiched in a single layer between 75 μm thick Kapton and imaged with x-rays. Although no particles were identified that exhibited unacceptable uranium dispersion as specified by the visual standard referenced in the AGR-1 fuel specification EDF-4380, many anomalies were noted during the examination of the x-ray images.

General comments

The fuel kernel blocks essentially all the x-rays producing an unexposed (white) circle in the x-ray image. The SiC partially stops the x-rays. This produces a mostly unexposed (white) ring around the outer edge of the particle where the x-ray path length is the greatest. The thickness of this ring is approximately the thickness of the SiC layer. Between the outer SiC ring and the inner kernel circle, the x-ray image typically shows a gradient in the contrast, going from gray at the outer SiC ring to black close to the kernel circle. The x-ray attenuation in the buffer and inner pyrocarbon (IPyC) layers is negligible.

Distinguishing x-ray attenuation due to uranium dispersion in the buffer and IPyC layer from x-ray attenuation due to the outer SiC layer is problematic. Initial calibrations to quantify the x-ray images and models for the current analysis system indicate that a dispersion of 1-2 wt% of the uranium in the kernel may be necessary to produce an image similar to those indicated as showing unacceptable dispersion in the visual standard. However, variations in SiC thickness and deviations from a perfect spherical shape can further complicate this analysis. Figure C-1 shows a series of images generated using an x-ray absorption model assuming a spherical baseline particle (minus OPyC) with various amounts of uranium uniformly distributed at the IPyC/buffer interface.

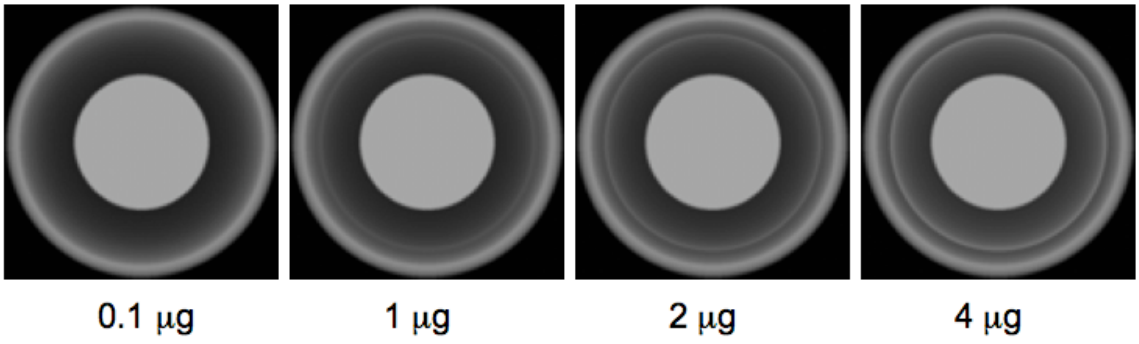


Figure C-1: Model of x-ray image for AGR-1 baseline particle with various amounts of U migrated to the IPyC/buffer interface.

Facets in the SiC layer

Facets and dimples in the SiC layer sometimes result in areas on the image of less exposure inside the SiC ring, such as can be seen in Figure C-2. This is due to an increased path length in the SiC. These bright streaks are clearly associated with a faceted area in the SiC layer and are not counted as defective particles for the defective IPyC analysis.

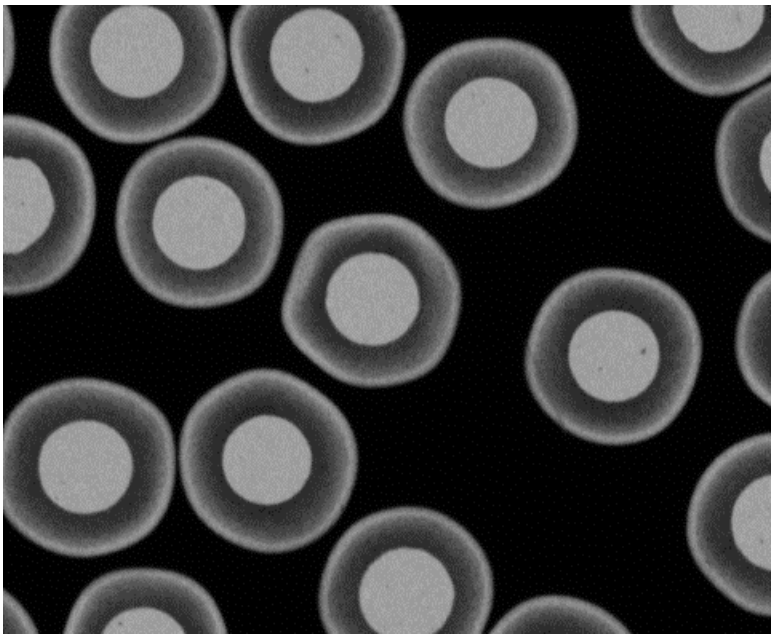


Figure C-2: Faceted or dimpled SiC layer.

Abnormal kernels

One commonly observed anomaly was undersized kernels, ranging between 200 and 300 μm diameter. 25 particles were noted to contain noticeably undersized kernels. 25 out of 49735 corresponds to a 95% confidence anomaly fraction of $\leq 7.1 \cdot 10^{-4}$ for the particles in the compact lot. An example of a particle with a 200 μm diameter undersized kernel is shown in Figure C-3. The source of the undersized kernels may be due to the inefficiency of sieving for eliminating small kernels or a kernel forming anomaly where small kernel spheres "hatch out" of normal sized kernels after insertion into the coating furnace. Because smaller particles tend to coat faster, these small kernels end up producing particles that are equivalent in size to the average TRISO and therefore are not removed by the roller-micrometer used to remove over- and under-sized particles.

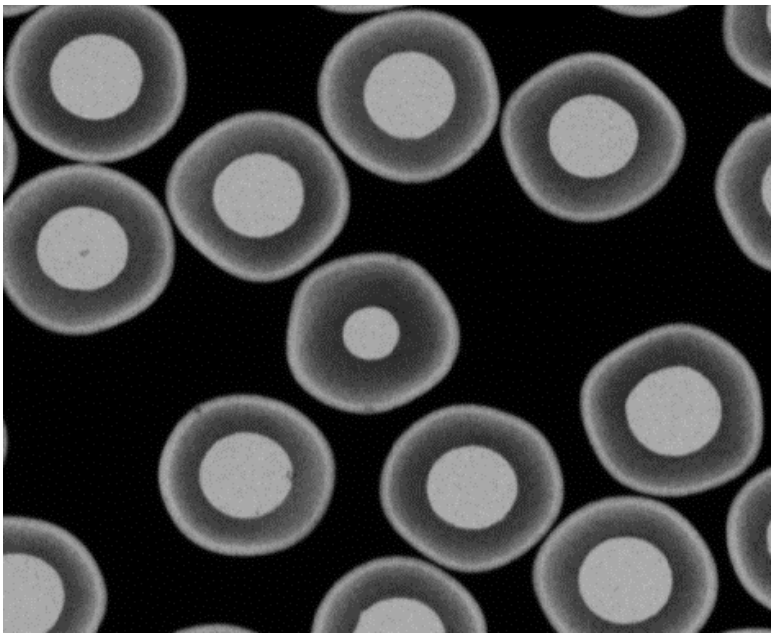


Figure C-3: x-ray image of particle with undersized kernel.

Particles with non-spherical kernels can also be seen in the x-ray images. Small dents and protrusions do not appear to propagate beyond the buffer to affect the shape of the SiC layer. However, more abnormally shaped kernels do affect the particle shape as in Figure C-4.

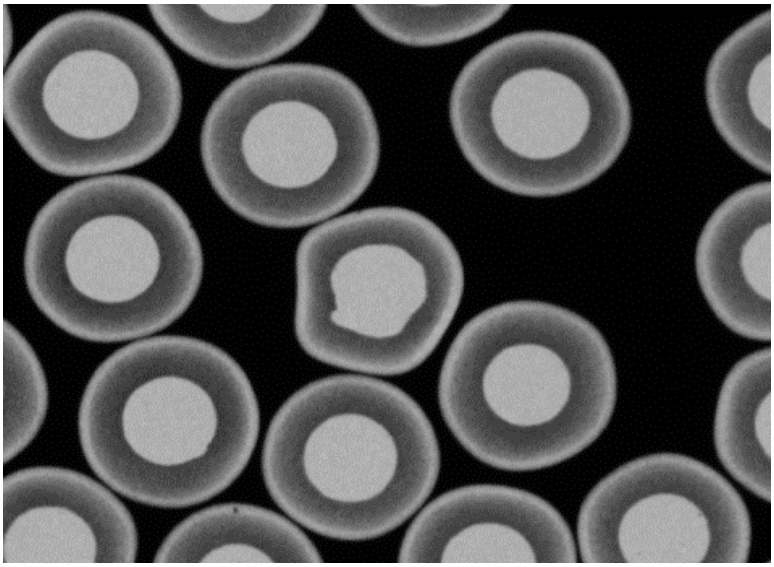


Figure C-4: x-ray image of particle with odd shaped kernel.

Abnormal SiC

Another commonly observed anomaly in the x-ray images of the particles was SiC that was less than half the average thickness of 35 μm. 15 particles were noted to have thin SiC. 15 out of 49735 corresponds to a 95% confidence anomaly fraction of $\leq 4.7 \cdot 10^{-4}$ for the particles in the compact lot. An example of a particle with approximately 15 μm thick SiC is shown in Figure C-5. In some of the particles with thin SiC, the SiC thickness clearly varied around the particle (Figure C-6). The thin SiC is probably caused by particles being ejected from the coating zone of the fluidized bed and temporarily adhering to the walls of the coating chamber.

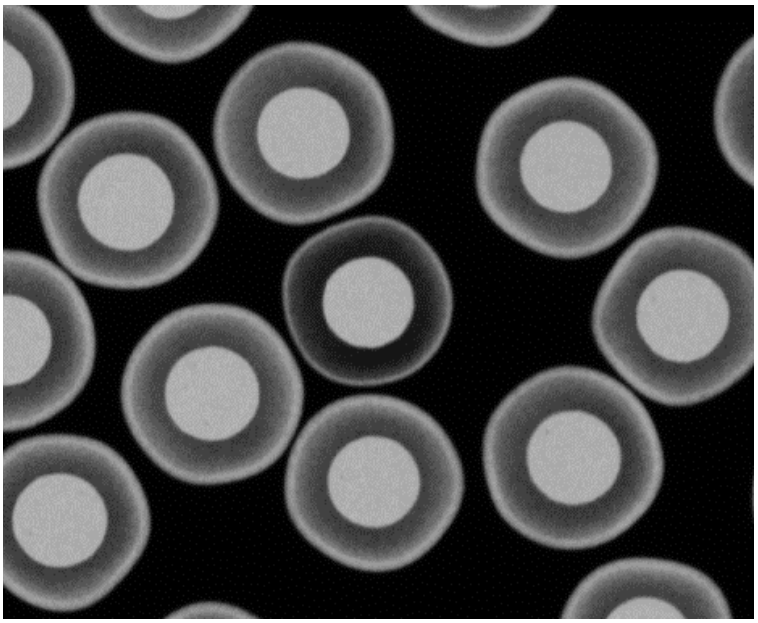


Figure C-5: x-ray image of particle with thin SiC.

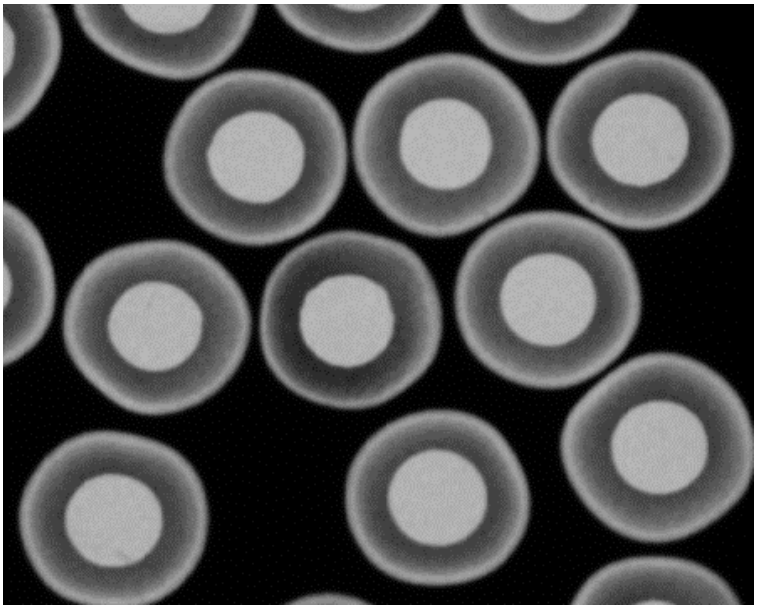


Figure C-6: x-ray image of particle with uneven SiC thickness.

Abnormal particle shapes

Four particles were noted that exhibited large protrusions, such as shown in Figure C-7. This anomaly is probably caused by the inclusion of carbon soot at the IPyC/SiC interface. These types of particle would normally be removed by the shape separation table, but it is known that the tabling is not 100% effective.

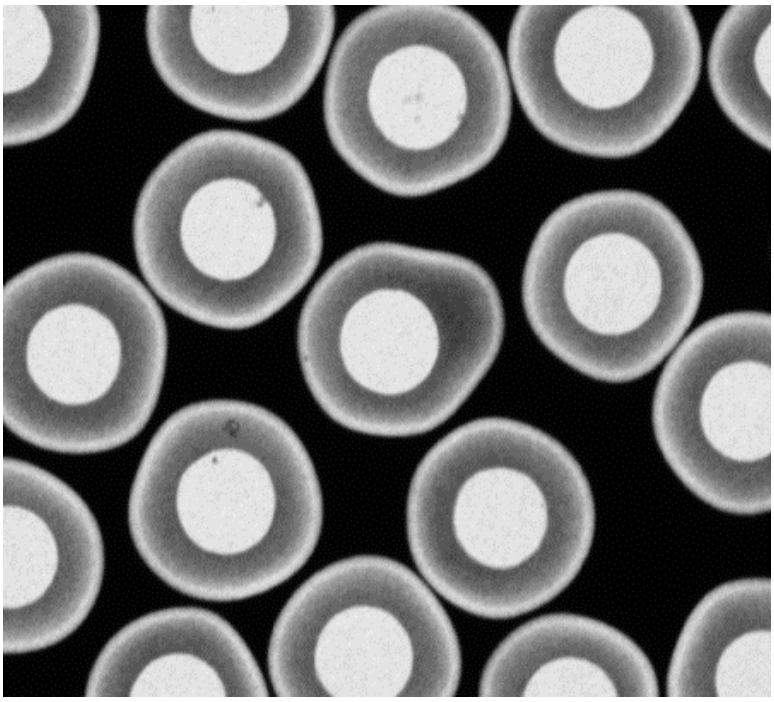


Figure C-7: x-ray image of a particle with a large protrusion.

Leach-Burn-Leach defects

Two of the four sets of 3 compacts exhibited 1 leach-burn-leach (LBL) defect each. The LBL defective particles were evident in the x-ray imaging of the particles recovered from that analysis. Figure C-8 shows a particle from compacts LEU01-46T-Z(40,48,64) where the kernel was removed by the nitric acid leach through a defect in the SiC which is not apparent in the x-ray image. Figure C-9 shows some SiC fragments from a particle in compacts LEU01-46T-Z(10,13,66).

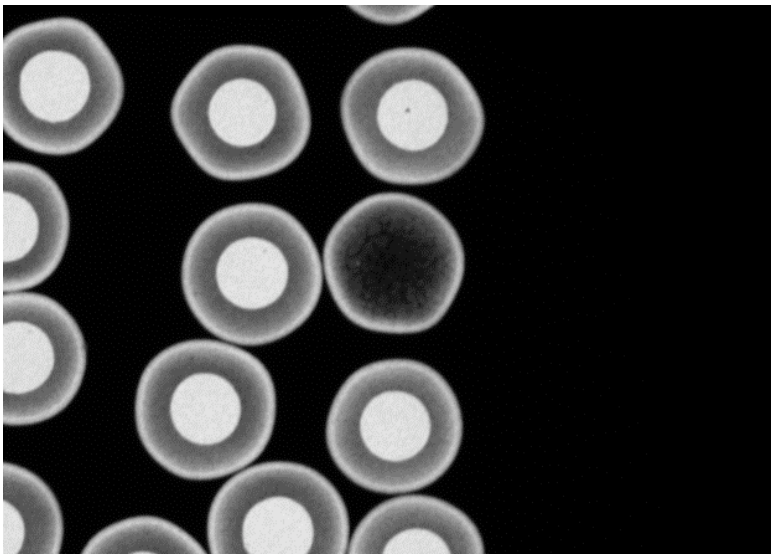


Figure C-8: x-ray image of LBL defect particle with leached out kernel.

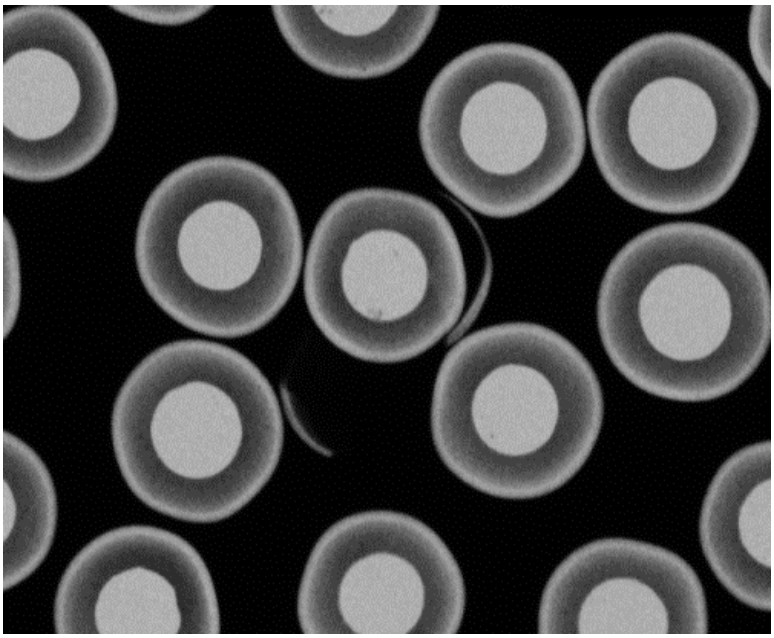


Figure C-9: x-ray image of SiC fragments from LBL defect particle.