OAK RIDGE
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FOR THE DEPARTMENT OF ENERGY

ORNL/TM-2007/019

Data Compilation for AGR-3/4 Driver Fuel Coated Particle Composite LEU03-09T

Revision 0

John D. Hunn and Richard A. Lowden

March 2007

UT-BATTELLE
ORNL-27 (4-00)

Data Compilation for AGR-3/4 Driver Fuel Coated Particle Composite LEU03-09T

John D. Hunn and Richard A. Lowden
Oak Ridge National Laboratory

This document is a compilation of characterization data for the AGR-3/4 driver fuel coated particle composite LEU03-09T, a composite of four batches of TRISO-coated, nominally 350 μm diameter, 19.7% low enrichment uranium oxide/uranium carbide kernels (LEUCO). The AGR-3/4 driver fuel particles were fabricated using the AGR-1 baseline coating conditions and 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 coated particles were produced by ORNL for the Advanced Gas Reactor Fuel Development and Qualification (AGR) program to be put into compacts, along with designed-to-fail particles, for insertion in the AGR-3 and AGR-4 irradiation test capsules. The kernels were obtained from BWXT and identified as composite G73V-20-69303. The BWXT kernel lot G73V-20-69303 was riffled into sublots for characterization and coating by ORNL and identified as LEU03-## (where ## is a series of integers beginning with 01).

Additional data is provided for measurements made on particle batches coated with only buffer or buffer plus inner pyrocarbon (IPyC) layers using similar process conditions as used for the full TRISO batches comprising the LEU01-09T composite. These batches were originally fabricated and tested for the AGR-1 campaign in order to qualify that the process conditions used for buffer and IPyC would produce acceptable densities, as described in sections 10 and 11. These qualifying batches used nominally 350 μm diameter natural uranium oxide/uranium carbide kernels (NUCO). The kernels were obtained from BWXT and identified as composite G73B-NU-69300. Additional supporting measurements are also provide on interrupted batches using kernels from the BWXT LEUCO kernel composite G73D-20-69302 and the ORNL depleted uranium oxide kernel composite DUN350.

The AGR-3 & -4 Fuel Product Specification (INL EDF-6638, Rev. 1) provides the requirements necessary for acceptance of the driver fuel manufactured for the AGR-3 and AGR-4 irradiation tests. Sections 5.2 and 5.3 of EDF-6638 provide the property requirements for the coated particle batches and coated particle composite. The Statistical Sampling Plan for AGR-3 and -4 Fuel Materials (INL EDF-6917, Rev. 1) provides additional guidance regarding statistical methods for product acceptance and recommended sample sizes. The procedures for characterizing and qualifying the particles are outlined in ORNL product inspection plans: AGR-CHAR-PIP-01, AGR-CHAR-PIP-02, AGR-CHAR-PIP-06, and AGR-CHAR-PIP-07. The inspection report forms generated by these product inspection plans document the product acceptance for the property requirements listed in sections 5.2 and 5.3 of EDF-6638.

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1 Summary of acceptance test results for LEU03-09T

This section contains inspection report forms (IRF's) associated with the coated particle composite LEU03-09T. These inspection report forms summarize the acceptance testing performed according to the product inspection plans: AGR-CHAR-PIP-02, AGR-CHAR-PIP-06, and AGR-CHAR-PIP-07. The information in these forms covers all the property specifications listed in sections 5.2 and 5.3 of the AGR-3 & -4 Fuel Product Specification (INL EDF-6638, Rev. 1). The coated particle composite, LEU03-09T, was found to meet all the requirements in these two sections of EDF-6638, Rev. 1.

These inspection report forms also appear in later sections of this compilation, accompanied by the associated data report forms showing the results of each individual measurement.

Table 1-1 is provided for quick reference. It gives the mean values of key variable properties of the coated particle composite, LEU03-09T. For standard deviations of the distribution of the measured values see the appropriate IRF. For discussions on the uncertainty in these values, see the associated data acquisition methods and data report forms. The kernel diameter and density values are from ORNL measurements made for information only. The buffer and IPyC densities in the table are averages of the means for the individual interrupted batches (including confirmation batches), rather than direct measurements on the composite. The OPyC density in the table is an average of the mean OPyC density for each batch weighted by the mass fraction of each batch in the composite.

Table 1-1: Quick reference table for key variable properties of LEU03-09T.

Property	Mean
Average kernel diameter (μm)	357.3
Kernel envelope density (Mg/m^3)	11.098
Average buffer thickness (μm)	109.7
Average IPyC thickness (μm)	40.4
Average SiC thickness (μm)	33.5
Average OPyC thickness (μm)	41.3
Buffer envelope density (Mg/m^3) (interrupted batches)	1.10
IPyC sink/float density (Mg/m^3) (interrupted batches)	1.904
SiC sink/float density (Mg/m^3)	3.2026
OPyC sink/float density (Mg/m^3) (weighted average)	1.901
IPyC anisotropy (BAFo equivalent)	1.027
OPyC anisotropy (BAFo equivalent)	1.021

Table 1-2 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 coated particle composite, LEU03-09T. In other words, these values are the lowest tolerance limits for which the composite 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 coated particle composite.

Table 1-2: Quick reference table for key attribute properties of LEU03-09T.

Property	Defect Fraction
Particles with SiC gold spot defects	$\leq 1.0 \times 10^{-3}$
Particle aspect ratio	$\leq 3.0 \times 10^{-3}$
Particles with missing OPyC	$\leq 9.7 \times 10^{-5}$

Inspection Report Form IRF-02A: Interrupted Coating Batches - Buffer Density

Procedure:	AGR-CHAR-PIP-02 Rev. 4
Batch 1 ID:	NUCO350-25B
Batch 1 description:	Buffer-coated BWXT kernel composite 69300
Batch 2 ID:	NUCO350-36B
Batch 2 description:	Buffer-coated BWXT kernel composite 69300
Batch 3 ID:	NUCO350-54B
Batch 3 description:	Buffer-coated BWXT kernel composite 69300

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	t value (t)	INL EDF-4380 Rev. 6				
Batch 1: Buffer envelope density (Mg/m^3)	1.08	0.04	5	2.132	mean 1.03 ± 0.15	A = x - ts/√n ≥ 0.88	1.04	pass	DRF-16 DRF-22
						B = x + ts/√n ≤ 1.18	1.12	pass	
Batch 2: Buffer envelope density (Mg/m^3)	1.11	0.05	5	2.132	mean 1.03 ± 0.15	A = x - ts/√n ≥ 0.88	1.06	pass	DRF-16 DRF-22
						B = x + ts/√n ≤ 1.18	1.16	pass	
Batch 3: Buffer envelope density (Mg/m^3)	1.11	0.04	5	2.132	mean 1.03 ± 0.15	A = x - ts/√n ≥ 0.88	1.07	pass	DRF-16 DRF-22
						B = x + ts/√n ≤ 1.18	1.15	pass	

Comments

Standard deviations are √5 times the uncertainties in buffer density (standard errors) reported on DRF-16.
Average thickness of buffer was 108 µm based on average envelope volume of 9.25E-5 cc (effective diameter of 561 µm) and average kernel diameter of 345 µm.
Average thickness of buffer was 108 µm based on average outer diameter of 561 µm obtained per DAM-10 and average kernel diameter of 345 µm.
Confirmatory batch on LEUCO kernels, LEU01-16E: mean buffer density = 1.10 g/cc.

John Kim — **QC Supervisor**

3-10-06 — **Date**

Accept process for buffer density (Yes or No):	Yes

QA Reviewer

3/29/06 — **Date**

Inspection Report Form IRF-02B: Interrupted Coating Batches - IPyC Density

Procedure:	AGR-CHAR-PIP-02 Rev. 4
Batch 1 ID:	NUCO350-30BI
Batch 1 description:	IPyC/Buffer on BWXT kernel composite 69300
Batch 2 ID:	NUCO350-37BI
Batch 2 description:	IPyC/Buffer on BWXT kernel composite 69300
Batch 3 ID:	NUCO350-29BI
Batch 3 description:	IPyC/Buffer on BWXT kernel composite 69300

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	k or t value	INL EDF-4380 Rev. 6				
Batch 1: IPyC sink/float density (Mg/m³)	1.8917	0.0113	25	1.711	mean 1.90 ± 0.05	A = x - ts/√n ≥ 1.85	1.888	pass	DRF-03
						B = x + ts/√n ≤ 1.95	1.896	pass	
				3.158	dispersion ≤0.01 ≤ 1.80 ≤0.01 ≥ 2.00	C = x - ks > 1.80	1.856	pass	
						D = x + ks < 2.00	1.927	pass	
Batch 2: IPyC sink/float density (Mg/m³)	1.9038	0.0153	21	1.725	mean 1.90 ± 0.05	A = x - ts/√n ≥ 1.85	1.898	pass	DRF-03
						B = x + ts/√n ≤ 1.95	1.910	pass	
				3.262	dispersion ≤0.01 ≤ 1.80 ≤0.01 ≥ 2.00	C = x - ks > 1.80	1.854	pass	
						D = x + ks < 2.00	1.954	pass	
Batch 3: IPyC sink/float density (Mg/m³)	1.9112	0.0142	20	1.729	mean 1.90 ± 0.05	A = x - ts/√n ≥ 1.85	1.906	pass	DRF-03
						B = x + ts/√n ≤ 1.95	1.917	pass	
				3.295	dispersion ≤0.01 ≤ 1.80 ≤0.01 ≥ 2.00	C = x - ks > 1.80	1.864	pass	
						D = x + ks < 2.00	1.958	pass	

Comments

95% confidence interval for Buffer thickness in composite = (104µm, 106µm) with <1% ≤55µm.
95% confidence interval for IPyC thickness in composite = (34.2µm, 34.9µm) with >1% ≤30µm and <1% ≥56µm.
Confirmatory batch on LEUCO kernels, LEU01-15I: mean IPyC density = 1.9074 g/cc.

QC Supervisor — Date: 3-10-06

Accept process for IPyC density (Yes or No):	Yes

QA Reviewer — Date: 3/29/06

Inspection Report Form IRF-06: Coated Particle Batches

Procedure:	AGR-CHAR-PIP-06 Rev. 0
Coated particle batch ID:	LEU03-03T
Coated particle batch description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	k or t value	INL EDF-6638 Rev. 1				
Average buffer thickness for each particle (μm)	111.2	8.2	187	1.653	mean 100 ± 15	A = x - ts/√n ≥ 85	110.2	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 115	112.2	pass	
Average IPyC thickness for each particle (μm)	40.3	2.3	239	1.651	mean 40 ± 5	A = x - ts/√n ≥ 35	40.1	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 45	40.5	pass	
Average SiC thickness for each particle (μm)	33.5	1.1	239	1.651	mean 35 ± 4	A = x - ts/√n ≥ 31	33.4	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 39	33.6	pass	
Average OPyC thickness for each particle (μm)	42.7	2.1	239	1.651	mean 40 ± 5	A = x - ts/√n ≥ 35	42.5	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 45	42.9	pass	
Particles with missing OPyC			15534		defect fraction ≤ 6.0×10^{-4}	≤4 in 15,500	0	pass	DRF-19
OPyC sink/float density (Mg/m³)	1.8929	0.0084	75	1.666	mean 1.90 ± 0.05	A = x - ts/√n ≥ 1.85	1.891	pass	DRF-03
						B = x + ts/√n ≤ 1.95	1.895	pass	
				2.743	dispersion ≤0.01 ≤ 1.80 ≤0.01 ≥ 2.00	C = x - ks > 1.80	1.870	pass	
						D = x + ks < 2.00	1.916	pass	

Comments

QC Supervisor	Date: 12-12-06

Accept Coated particle batch (Yes or No):	Yes

QA Reviewer	Date: 12/13/06

Inspection Report Form IRF-06: Coated Particle Batches

Procedure:	AGR-CHAR-PIP-06 Rev. 0
Coated particle batch ID:	LEU03-04T
Coated particle batch description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	k or t value	INL EDF-6638 Rev. 1				
Average buffer thickness for each particle (μm)	109.1	8.6	204	1.652	mean 100 ± 15	A = x - ts/√n ≥ 85	108.1	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 115	110.1	pass	
Average IPyC thickness for each particle (μm)	39.8	2.1	229	1.652	mean 40 ± 5	A = x - ts/√n ≥ 35	39.6	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 45	40.0	pass	
Average SiC thickness for each particle (μm)	32.6	1.3	229	1.652	mean 35 ± 4	A = x - ts/√n ≥ 31	32.5	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 39	32.7	pass	
Average OPyC thickness for each particle (μm)	40.4	1.8	229	1.652	mean 40 ± 5	A = x - ts/√n ≥ 35	40.2	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 45	40.6	pass	
Particles with missing OPyC			15558		defect fraction ≤ 6.0×10^{-4}	≤4 in 15,500	0	pass	DRF-19
OPyC sink/float density (Mg/m³)	1.9153	0.0070	49	1.677	mean 1.90 ± 0.05	A = x - ts/√n ≥ 1.85	1.914	pass	DRF-03
						B = x + ts/√n ≤ 1.95	1.917	pass	
				2.861	dispersion ≤0.01 ≤ 1.80 ≤0.01 ≥ 2.00	C = x - ks > 1.80	1.895	pass	
						D = x + ks < 2.00	1.935	pass	

Comments

John Thorn — **QC Supervisor**

12-12-06 — **Date**

Accept Coated particle batch (Yes or No):	Yes

M. C. Fox — **QA Reviewer**

12/13/06 — **Date**

Inspection Report Form IRF-06: Coated Particle Batches

Procedure:	AGR-CHAR-PIP-06 Rev. 0
Coated particle batch ID:	LEU03-05T
Coated particle batch description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	k or t value	INL EDF-6638 Rev. 1				
Average buffer thickness for each particle (µm)	111.7	8.2	235	1.651	mean 100 ± 15	A = x - ts/√n ≥ 85	110.8	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 115	112.6	pass	
Average IPyC thickness for each particle (µm)	40.5	2.3	236	1.651	mean 40 ± 5	A = x - ts/√n ≥ 35	40.3	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 45	40.7	pass	
Average SiC thickness for each particle (µm)	32.9	1.1	236	1.651	mean 35 ± 4	A = x - ts/√n ≥ 31	32.8	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 39	33.0	pass	
Average OPyC thickness for each particle (µm)	41.5	1.9	236	1.651	mean 40 ± 5	A = x - ts/√n ≥ 35	41.3	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 45	41.7	pass	
Particles with missing OPyC			15553		defect fraction ≤ 6.0 x 10^{-4}	≤4 in 15,500	0	pass	DRF-19
OPyC sink/float density (Mg/m^3)	1.9029	0.0098	52	1.675	mean 1.90 ± 0.05	A = x - ts/√n ≥ 1.85	1.901	pass	DRF-03
						B = x + ts/√n ≤ 1.95	1.905	pass	
				2.842	dispersion ≤0.01 ≤ 1.80 ≤0.01 ≥ 2.00	C = x - ks > 1.80	1.875	pass	
						D = x + ks < 2.00	1.931	pass	

Comments

12-12-06

QC Supervisor | **Date**

Accept Coated particle batch (Yes or No):	Yes

12/13/06

QA Reviewer | **Date**

Inspection Report Form IRF-06: Coated Particle Batches

Procedure:	AGR-CHAR-PIP-06 Rev. 0
Coated particle batch ID:	LEU03-06T
Coated particle batch description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	k or t value	INL EDF-6638 Rev. 1				
Average buffer thickness for each particle (μm)	113.4	8.1	232	1.651	mean 100 ± 15	A = x - ts/√n ≥ 85	112.5	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 115	114.3	pass	
Average IPyC thickness for each particle (μm)	39.9	2.2	237	1.651	mean 40 ± 5	A = x - ts/√n ≥ 35	39.7	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 45	40.1	pass	
Average SiC thickness for each particle (μm)	32.0	1.0	237	1.651	mean 35 ± 4	A = x - ts/√n ≥ 31	31.9	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 39	32.1	pass	
Average OPyC thickness for each particle (μm)	40.5	1.9	237	1.651	mean 40 ± 5	A = x - ts/√n ≥ 35	40.3	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 45	40.7	pass	
Particles with missing OPyC			15600		defect fraction ≤ 6.0×10^{-4}	≤4 in 15,500	0	pass	DRF-19
OPyC sink/float density (Mg/m³)	1.8945	0.0057	41	1.684	mean 1.90 ± 0.05	A = x - ts/√n ≥ 1.85	1.893	pass	DRF-03
						B = x + ts/√n ≤ 1.95	1.896	pass	
				2.922	dispersion ≤0.01 ≤ 1.80 ≤0.01 ≥ 2.00	C = x - ks > 1.80	1.878	pass	
						D = x + ks < 2.00	1.911	pass	

Comments

QC Supervisor — 12-12-06 — Date

Accept Coated particle batch (Yes or No):	Yes

QA Reviewer — 12/13/06 — Date

Inspection Report Form IRF-07: Coated Particle Composites

Procedure:	AGR-CHAR-PIP-07 Rev. 0
Coated particle composite ID:	LEU03-09T
Coated particle composite description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	k or t value	INL EDF-6638 Rev. 1				
Average buffer thickness for each particle (µm)	109.7	7.7	192	1.653	mean 100 ± 15	A = x - ts/√n ≥ 85	108.8	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 115	110.6	pass	
				2.573	dispersion ≤0.01 ≤ 55	C = x - ks > 55	89.9	pass	
Average IPyC thickness for each particle (µm)	40.4	2.3	226	1.652	mean 40 ± 4	A = x - ts/√n ≥ 36	40.1	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 44	40.7	pass	
				2.552	dispersion ≤0.01 ≤ 30 ≤0.01 ≥ 56	C = x - ks > 30	34.5	pass	
						D = x + ks < 56	46.3	pass	
Average SiC thickness for each particle (µm)	33.5	1.1	227	1.652	mean 35 ± 3	A = x - ts/√n ≥ 32	33.4	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 38	33.6	pass	
				2.552	dispersion ≤0.01 ≤ 25	C = x - ks > 25	30.7	pass	
Average OPyC thickness for each particle (µm)	41.3	2.1	227	1.652	mean 40 ± 4	A = x - ts/√n ≥ 36	41.1	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 44	41.5	pass	
				2.552	dispersion ≤0.01 ≤ 20	C = x - ks > 20	35.9	pass	
Buffer envelope density	See IRF-02A							pass	IRF-02A
IPyC sink/float density	See IRF-02B							pass	IRF-02B
SiC sink/float density (Mg/m³)	3.2026	0.0024	50	1.677	mean ≥ 3.19	A = x - ts/√n ≥ 3.19	3.202	pass	DRF-02
				2.863	dispersion ≤0.01 ≤ 3.17	C = x - ks > 3.17	3.196	pass	
IPyC anisotropy (BAFo equivalent)	1.027	0.002	10	1.833	mean ≤ 1.035	B = x + ts/√n ≤ 1.035	1.028	pass	DRF-18
				3.981	dispersion ≤0.01 ≥1.06	D = x + ks < 1.06	1.035	pass	
OPyC anisotropy (BAFo equivalent)	1.021	0.002	10	1.833	mean ≤ 1.035	B = x + ts/√n ≤ 1.035	1.022	pass	DRF-18
				3.981	dispersion ≤0.01 ≥1.06	D = x + ks < 1.06	1.029	pass	
Particles with SiC gold spot defects			43040		defect fraction ≤ 1.0 x 10^{-3}	≤6 in 12,000 or ≤14 in 22,000	32	pass	DRF-20
Particle aspect ratio			1584		dispersion ≤0.01 ≥1.14	≤1 in 500 or ≤7 in 1420	1	pass	DRF-07 DRF-10
Particles with missing OPyC			31089		defect fraction ≤ 3.0 x 10^{-4}	≤4 in 31,000	0	pass	DRF-19
SiC microstructure			3		comparison to visual standard	all imaged pass visual standard comparison	3	pass	DRF-23

Comments

Buffer and IPyC coating conditions for all batches in composite satisfied criteria in Table 5.3 footnote c of EDF-6638, Rev. 1.
32 out of 43040 gold spot defects passes the acceptance criterion of ≤32 in 42977 indicating ≤1E-3 defects with 95% confidence.
NCR-X-AGR-07-01 was issued to document the use of a furnace controller overdue for calibration verification, data was not affected.
NCR-X-AGR-07-02 was issued to document a 7 µm discrepancy between roller micrometer upper diameter control limit and specified value.

QC Supervisor

3-12-07
Date

Accept coated particle composite (Yes or No):	Yes

QA Reviewer

3/12/07
Date

2 Product ID's associated with LEU03-09T

Kernels

LEU03-## (from BWXT G73V-20-69303)
NUCO350-## (from BWXT G73B-NU-69300)
LEU01-## (from BWXT G73D-20-69302)
DUN350 (produced at ORNL)

Buffer-only particles

NUCO350-25B (Buffer density qualification batch 1)
NUCO350-36B (Buffer density qualification batch 2)
NUCO350-54B (Buffer density qualification batch 3)
NUCO350-58B (composite of 25B+36B+54B, for information only)
LEU01-16B (confirmation on LEU01 kernels, for information only)
DUN350-19B (confirmation on DUN350 kernels, for information only)

IPyC/Buffer-only particles

NUCO350-30BI (IPyC density qualification batch 1)
NUCO350-37BI (IPyC density qualification batch 2)
NUCO350-29BI (IPyC density qualification batch 3)
NUCO350-66BI (composite of 30BI+37BI+29BI, for information only)
LEU01-15I (confirmation on LEUCO kernels, for information only)

TRISO-coated particles

LEU03-03T (TRISO batch 1)
LEU03-04T (TRISO batch 2)
LEU03-05T (TRISO batch 3)
LEU03-06T (TRISO batch 4)
LEU03-09T (composite of 03T+04T+05T+06T)

3 Coating process conditions

The following pages contain coating process conditions for all coated particle batches associated with the LEU03-09T coated particle composite. These particles were coated within the baseline process conditions listed in section 3.1 of the AGR-3 & -4 Fuel Product Specification (INL EDF-6638, Rev. 0).

Buffer-only interrupted batches

NUCO350-25B (Buffer density qualification batch 1)
NUCO350-36B (Buffer density qualification batch 2)
NUCO350-54B (Buffer density qualification batch 3)
LEU01-16B (confirmation on LEUCO kernels, for information only)
DUN350-19B (confirmation on DUN350 kernels, for information only)

IPyC/Buffer-only interrupted batches

NUCO350-30BI (IPyC density qualification batch 1)
NUCO350-37BI (IPyC density qualification batch 2)
NUCO350-29BI (IPyC density qualification batch 3)
LEU01-15I (confirmation on LEUCO kernels, for information only)

TRISO-coated batches

LEU03-03T (TRISO batch 1)
LEU03-04T (TRISO batch 2)
LEU03-05T (TRISO batch 3)
LEU03-06T (TRISO batch 4)

Summary for Baseline Buffer Qualification Run – NUCO350-25B

Coating Run No.		NUCO350-25B
Description:		Baseline processing conditions for Buffer layer
Procedure:		AGR-COAT-SOP-01, Rev. 1
Kernel Lot No.		NUCO350-25
Operator:		R. A. Lowden
Date:		06/17/2005
Data Location:		B002249, Coating Log, Volume 1, pp. 202 - 212
Kernel Batch Wt.		62.11 g
Coated Particle Batch Wt.		81.33 g
	AGR-1 Parameter	**As-Processed**
Buffer		
Coating gases	C_2H_2 + Ar	C_2H_2 + Ar
TGF		8530 sccm
CGF	0.60 ± 0.10	0.61
Temperature	1450 ± 25°C	1450°C
Time		5 min
IPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	
TGF		
CGF	0.30 ± 0.03	
CGR	0.85 ± 0.085	
Temperature	1265 ± 25°C	
Time		
SiC		
Coating gases	H_2 + MTS	
TGF		
CGF	0.015 ± 0.005	
Temperature	1500 ± 25°C	
Time		
OPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	
TGF		
CGF	0.30 ± 0.03	
CGR	0.85 ± 0.085	
Temperature	1290 ± 40°C	
Time		
Comments/Notes:		

Operator:	Richard A. Lowden	Date:	6/17/05
QAS:	M. C. Lee	Date:	3/30/06

Summary for Baseline Buffer Qualification Run – NUCO350-36B

Coating Run No.	NUCO350-36B	
Description:	Baseline processing conditions for Buffer layer	
Procedure:	AGR-COAT-SOP-01, Rev. 1	
Kernel Lot No.	NUCO350-36	
Operator:	R. A. Lowden	
Date:	06/17/2005	
Data Location:	B002249, Coating Log, Volume 1, pp. 214 - 223	
Kernel Batch Wt.	61.97 g	
Coated Particle Batch Wt.	81.50 g	
	AGR-1 Parameter	**As-Processed**
Buffer		
Coating gases	C_2H_2 + Ar	C_2H_2 + Ar
TGF		8530 sccm
CGF	0.60 ± 0.10	0.61
Temperature	1450 ± 25°C	1450°C
Time		5 min
IPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	
TGF		
CGF	0.30 ± 0.03	
CGR	0.85 ± 0.085	
Temperature	1265 ± 25°C	
Time		
SiC		
Coating gases	H_2 + MTS	
TGF		
CGF	0.015 ± 0.005	
Temperature	1500 ± 25°C	
Time		
OPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	
TGF		
CGF	0.30 ± 0.03	
CGR	0.85 ± 0.085	
Temperature	1290 ± 40°C	
Time		
Comments/Notes:		

Operator:	[signature]	Date:	6/17/05
QAS:	[signature]	Date:	3/30/06

Summary for Baseline Buffer Qualification Run – NUCO350-54B

Coating Run No.		NUCO350-54B
Description:		Baseline processing conditions for Buffer layer
Procedure:		AGR-COAT-SOP-01, Rev. 1
Kernel Lot No.		NUCO350-54
Operator:		R. A. Lowden
Date:		06/20/2005
Data Location:		B002249, Coating Log, Volume 1, pp. 224 - 233
Kernel Batch Wt.		62.08 g
Coated Particle Batch Wt.		81.47 g
	AGR-1 Parameter	**As-Processed**
Buffer		
Coating gases	C_2H_2 + Ar	C_2H_2 + Ar
TGF		8530 sccm
CGF	0.60 ± 0.10	0.61
Temperature	1450 ± 25°C	1450°C
Time		5 min
IPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	
TGF		
CGF	0.30 ± 0.03	
CGR	0.85 ± 0.085	
Temperature	1265 ± 25°C	
Time		
SiC		
Coating gases	H_2 + MTS	
TGF		
CGF	0.015 ± 0.005	
Temperature	1500 ± 25°C	
Time		
OPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	
TGF		
CGF	0.30 ± 0.03	
CGR	0.85 ± 0.085	
Temperature	1290 ± 40°C	
Time		
Comments/Notes:		
Operator: Richard A Lowden	Date: 6/20/05	
QAS:	Date: 3/30/06	

Summary for Baseline Buffer Qualification Run – LEU01-16B

Coating Run No.		LEU01-16B
Description:		Baseline processing conditions for Buffer layer
Procedure:		AGR-COAT-SOP-01, Rev. 1
Kernel Lot No.		LEU01-16K
Operator:		R. A. Lowden
Date:		11/03/2005
Data Location:		B002516, Coating Log, Volume 3, pp. 2 – 10
Kernel Batch Wt.		63.30 g
Coated Particle Batch Wt.		82.57 g
	AGR-1 Parameter	**As-Processed**
Buffer		
Coating gases	C_2H_2 + Ar	C_2H_2 + Ar
TGF		8530 sccm
CGF	0.60 ± 0.10	0.61
Temperature	1450 ± 25°C	1450°C
Time		5 min
IPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	
TGF		
CGF	0.30 ± 0.03	
CGR	0.85 ± 0.085	
Temperature	1265 ± 25°C	
Time		
SiC		
Coating gases	H_2 + MTS	
TGF		
CGF	0.015 ± 0.005	
Temperature	1500 ± 25°C	
Time		
OPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	
TGF		
CGF	0.30 ± 0.03	
CGR	0.85 ± 0.085	
Temperature	1290 ± 40°C	
Time		
Comments/Notes:		

Operator:	Richard A Lowden	Date:	11/3/05
QAS:		Date:	3/30/06

Summary for Baseline Buffer Qualification Run – DUN350-19B

Coating Run No.		DUN350-19B
Description:		Baseline processing conditions for Buffer layer
Procedure:		AGR-COAT-SOP-01, Rev. 1
Kernel Lot No.		DUN350-19K
Operator:		R. A. Lowden
Date:		8/18/2006
Data Location:		B002517, Coating Log, Volume 4, pp. 254 – 263
Kernel Batch Wt.		64.38 g
Coated Particle Batch Wt.		84.78 g
	AGR-1 Parameter	**As-Processed**
Buffer		
Coating gases	C_2H_2 + Ar	C_2H_2 + Ar
TGF		8540 sccm
CGF	0.60 ± 0.10	0.61
Temperature	1450 ± 25°C	1450°C
Time		5 min
IPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	
TGF		
CGF	0.30 ± 0.03	
CGR	0.85 ± 0.085	
Temperature	1265 ± 25°C	
Time		
SiC		
Coating gases	H_2 + MTS	
TGF		
CGF	0.015 ± 0.005	
Temperature	1500 ± 25°C	
Time		
OPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	
TGF		
CGF	0.30 ± 0.03	
CGR	0.85 ± 0.085	
Temperature	1290 ± 40°C	
Time		
Comments/Notes:		

Operator:	Richard A. Lowden	Date:	8/18/06
QAS:	M. C. Lowden	Date:	2/2/07

Summary for Baseline IPyC Qualification Run – NUCO350-30BI

Coating Run No.	NUCO350-30BI	
Description:	Baseline processing conditions for IPyC layer	
Procedure:	AGR-COAT-SOP-01, Rev. 1	
Kernel Lot No.	NUCO350-30	
Operator:	R. A. Lowden	
Date:	06/29/2005	
Data Location:	B002249, Coating Log, Volume 1, pp. 260 - 268	
Kernel Batch Wt.	61.87 g	
Coated Particle Batch Wt.	104.34 g	
	AGR-1 Parameter	**As-Processed**
Buffer		
Coating gases	C_2H_2 + Ar	C_2H_2 + Ar
TGF		8530 sccm
CGF	0.60 ± 0.10	0.61
Temperature	1450 ± 25°C	1450°C
Time		5 min
IPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	Ar + C_2H_2 + C_3H_6
TGF		9430 sccm
CGF	0.30 ± 0.03	0.30
CGR	0.85 ± 0.085	0.85
Temperature	1265 ± 25°C	1265°C
Time		13 min
SiC		
Coating gases	H_2 + MTS	
TGF		
CGF	0.015 ± 0.005	
Temperature	1500 ± 25°C	
Time		
OPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	
TGF		
CGF	0.30 ± 0.03	
CGR	0.85 ± 0.085	
Temperature	1290 ± 40°C	
Time		
Comments/Notes:		

Operator:	Richard A. Lowden	Date:	6/29/05
QAS:		Date:	3/30/06

Summary for Baseline IPyC Qualification Run – NUCO350-37BI

Coating Run No.		NUCO350-37BI
Description:		Baseline processing conditions for IPyC layer
Procedure:		AGR-COAT-SOP-01, Rev. 1
Kernel Lot No.		NUCO350-37
Operator:		R. A. Lowden
Date:		06/30/2005
Data Location:		B002249, Coating Log, Volume 1, pp. 270 - 278
Kernel Batch Wt.		61.92 g
Coated Particle Batch Wt.		103.45 g
	AGR-1 Parameter	**As-Processed**
Buffer		
Coating gases	C_2H_2 + Ar	C_2H_2 + Ar
TGF		8530 sccm
CGF	0.60 ± 0.10	0.61
Temperature	1450 ± 25°C	1450°C
Time		5 min
IPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	Ar + C_2H_2 + C_3H_6
TGF		9430 sccm
CGF	0.30 ± 0.03	0.30
CGR	0.85 ± 0.085	0.85
Temperature	1265 ± 25°C	1265°C
Time		13 min
SiC		
Coating gases	H_2 + MTS	
TGF		
CGF	0.015 ± 0.005	
Temperature	1500 ± 25°C	
Time		
OPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	
TGF		
CGF	0.30 ± 0.03	
CGR	0.85 ± 0.085	
Temperature	1290 ± 40°C	
Time		
Comments/Notes:		

Operator:	Richard A. Lowden	Date:	6/30/05
QAS:	M. C. Lee	Date:	3/30/06

Summary for Baseline IPyC Qualification Run – NUCO350-29BI

Coating Run No.		NUCO350-29BI
Description:		Baseline processing conditions for IPyC layer
Procedure:		AGR-COAT-SOP-01, Rev. 1
Kernel Lot No.		NUCO350-29
Operator:		R. A. Lowden
Date:		07/01/2005
Data Location:		B002249, Coating Log, Volume 1, pp. 279 - 287
Kernel Batch Wt.		62.52 g
Coated Particle Batch Wt.		105.56 g
	AGR-1 Parameter	**As-Processed**
Buffer		
Coating gases	C_2H_2 + Ar	C_2H_2 + Ar
TGF		8530 sccm
CGF	0.60 ± 0.10	0.61
Temperature	1450 ± 25°C	1450°C
Time		5 min
IPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	Ar + C_2H_2 + C_3H_6
TGF		9430 sccm
CGF	0.30 ± 0.03	0.30
CGR	0.85 ± 0.085	0.85
Temperature	1265 ± 25°C	1265°C
Time		13 min
SiC		
Coating gases	H_2 + MTS	
TGF		
CGF	0.015 ± 0.005	
Temperature	1500 ± 25°C	
Time		
OPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	
TGF		
CGF	0.30 ± 0.03	
CGR	0.85 ± 0.085	
Temperature	1290 ± 40°C	
Time		
Comments/Notes:		

Operator:	Richard A Lowden	Date:	7/1/05
QAS:		Date:	3/30/06

Summary for Baseline IPyC Qualification Run – LEU01-15I

Coating Run No.	LEU01-15I	
Description:	Baseline processing conditions for IPyC layer	
Procedure:	AGR-COAT-SOP-01, Rev. 1	
Kernel Lot No.	LEU01-15K	
Operator:	R. A. Lowden	
Date:	11/04/2005	
Data Location:	B002516, Coating Log, Volume 3, pp. 12 – 20	
Kernel Batch Wt.	63.27 g	
Coated Particle Batch Wt.	108.96 g	
	AGR-1 Parameter	**As-Processed**
Buffer		
Coating gases	C_2H_2 + Ar	C_2H_2 + Ar
TGF		8530 sccm
CGF	0.60 ± 0.10	0.61
Temperature	1450 ± 25°C	1450°C
Time		5 min
IPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	Ar + C_2H_2 + C_3H_6
TGF		9430 sccm
CGF	0.30 ± 0.03	0.30
CGR	0.85 ± 0.085	0.85
Temperature	1265 ± 25°C	1265°C
Time		13 min
SiC		
Coating gases	H_2 + MTS	
TGF		
CGF	0.015 ± 0.005	
Temperature	1500 ± 25°C	
Time		
OPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	
TGF		
CGF	0.30 ± 0.03	
CGR	0.85 ± 0.085	
Temperature	1290 ± 40°C	
Time		
Comments/Notes:		

Operator:	Richard A Lowden	Date:	11/4/05
QAS:		Date:	3/30/06

Summary for Baseline Coating Run - LEU03-03T

Coating Run No.		LEU03-03T
Description:		Baseline AGR-1 processing conditions
Procedure:		AGR-COAT-SOP-01, Rev. 1
Kernel Lot No.		LEU03-03K
Operator:		R. A. Lowden
Date:		08/29/2006
Data Location:		B002517, Coating Log, Volume 4, pp. 264 - 273
Kernel Batch Wt.		66.12 g
Coated Particle Batch Wt.		194.34 g
	AGR-1 Parameter	**As-Processed**
Buffer		
Coating gases	C_2H_2 + Ar	C_2H_2 + Ar
TGF		8540 sccm
CGF	0.60 ± 0.10	0.61
Temperature	1450 ± 25°C	1450°C
Time		5 min
IPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	Ar + C_2H_2 + C_3H_6
TGF		9430 sccm
CGF	0.30 ± 0.03	0.30
CGR	0.85 ± 0.085	0.85
Temperature	1265 ± 25°C	1265°C
Time		12.33 min
SiC		
Coating gases	H_2 + MTS	H_2 + MTS
TGF		16,607 sccm
CGF	0.015 ± 0.005	0.0112
Temperature	1500 ± 25°C	1500°C
Time		140 min
OPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	Ar + C_2H_2 + C_3H_6
TGF		16,215 sccm
CGF	0.30 ± 0.03	0.30
CGR	0.85 ± 0.085	0.85
Temperature	1290 ± 40°C	1290°C
Time		10 min
Comments/Notes:		

Operator:	Richard A. Lowden	Date:	9/8/06
QAS:	M.C.	Date:	9/11/06

Summary for Baseline Coating Run - LEU03-04T

Coating Run No.		LEU03-04T
Description:		Baseline AGR-1 processing conditions
Procedure:		AGR-COAT-SOP-01, Rev. 1
Kernel Lot No.		LEU03-04K
Operator:		R. A. Lowden
Date:		08/30/2006
Data Location:		B002517, Coating Log, Volume 4, pp. 274 - 283
Kernel Batch Wt.		66.05 g
Coated Particle Batch Wt.		190.54 g
	AGR-1 Parameter	**As-Processed**
Buffer		
Coating gases	C_2H_2 + Ar	C_2H_2 + Ar
TGF		8540 sccm
CGF	0.60 ± 0.10	0.61
Temperature	1450 ± 25°C	1450°C
Time		5 min
IPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	Ar + C_2H_2 + C_3H_6
TGF		9430 sccm
CGF	0.30 ± 0.03	0.30
CGR	0.85 ± 0.085	0.85
Temperature	1265 ± 25°C	1265°C
Time		12.33 min
SiC		
Coating gases	H_2 + MTS	H_2 + MTS
TGF		16,607 sccm
CGF	0.015 ± 0.005	0.0113
Temperature	1500 ± 25°C	1500°C
Time		140 min
OPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	Ar + C_2H_2 + C_3H_6
TGF		16,215 sccm
CGF	0.30 ± 0.03	0.30
CGR	0.85 ± 0.085	0.85
Temperature	1290 ± 40°C	1290°C
Time		10 min
Comments/Notes:		

Operator:	Richard A Lowden	Date:	9/8/06
QAS:	M.C. Davis	Date:	9/11/06

Summary for Baseline Coating Run - LEU03-05T

Coating Run No.	LEU03-05T	
Description:	Baseline AGR-1 processing conditions	
Procedure:	AGR-COAT-SOP-01, Rev. 1	
Kernel Lot No.	LEU03-05K	
Operator:	R. A. Lowden	
Date:	09/01/2006	
Data Location:	B002517, Coating Log, Volume 4, pp. 284 - 295	
Kernel Batch Wt.	66.11 g	
Coated Particle Batch Wt.	192.66 g	
	AGR-1 Parameter	**As-Processed**
Buffer		
Coating gases	C_2H_2 + Ar	C_2H_2 + Ar
TGF		8540 sccm
CGF	0.60 ± 0.10	0.61
Temperature	1450 ± 25°C	1450°C
Time		5 min
IPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	Ar + C_2H_2 + C_3H_6
TGF		9430 sccm
CGF	0.30 ± 0.03	0.30
CGR	0.85 ± 0.085	0.85
Temperature	1265 ± 25°C	1265°C
Time		12.33 min
SiC		
Coating gases	H_2 + MTS	H_2 + MTS
TGF		16,606 sccm
CGF	0.015 ± 0.005	0.0112
Temperature	1500 ± 25°C	1500°C
Time		140 min
OPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	Ar + C_2H_2 + C_3H_6
TGF		16,215 sccm
CGF	0.30 ± 0.03	0.30
CGR	0.85 ± 0.085	0.85
Temperature	1290 ± 40°C	1290°C
Time		10 min
Comments/Notes:		

Operator:	Richard A. Lowden	Date:	9/8/06
QAS:	M. C. Davis	Date:	9/11/06

Summary for Baseline Coating Run - LEU03-06T

Coating Run No.	LEU03-06T	
Description:	Baseline AGR-1 processing conditions	
Procedure:	AGR-COAT-SOP-01, Rev. 1	
Kernel Lot No.	LEU03-06K	
Operator:	R. A. Lowden	
Date:	09/06/2006	
Data Location:	B002517, Coating Log, Volume 4, pp. 296 - 305	
Kernel Batch Wt.	66.10 g	
Coated Particle Batch Wt.	190.84 g	
	AGR-1 Parameter	**As-Processed**
Buffer		
Coating gases	C_2H_2 + Ar	C_2H_2 + Ar
TGF		8540 sccm
CGF	0.60 ± 0.10	0.61
Temperature	1450 ± 25°C	1450°C
Time		5 min
IPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	Ar + C_2H_2 + C_3H_6
TGF		9430 sccm
CGF	0.30 ± 0.03	0.30
CGR	0.85 ± 0.085	0.85
Temperature	1265 ± 25°C	1265°C
Time		12.33 min
SiC		
Coating gases	H_2 + MTS	H_2 + MTS
TGF		16,605 sccm
CGF	0.015 ± 0.005	0.0111
Temperature	1500 ± 25°C	1500°C
Time		140 min
OPyC		
Coating gases	Ar + C_2H_2 + C_3H_6	Ar + C_2H_2 + C_3H_6
TGF		16,215 sccm
CGF	0.30 ± 0.03	0.30
CGR	0.85 ± 0.085	0.85
Temperature	1290 ± 40°C	1290°C
Time		10 min
Comments/Notes:		

Operator:	Richard A Lowden	Date:	9/8/06
QAS:	M. C. Lin	Date:	9/11/06

4 Classification of coated particles

Fully-coated batches of particles were sorted employing a sizing technique described in AGR-ROLLER-SOP-1, Rev. 0 and a tabling method described in AGR-TABLER-SOP-1, Rev. 1 as required in section 5.1 of the AGR-3 & -4 Fuel Product Specification (INL EDF-6638, Rev. 1). The purpose of this classification is to remove aspherical particles and particles outside a specified diameter range. Details regarding the application of the procedures to the classification of coated particle batches can be found in the logbooks referenced on the summary sheets.

Particles can be sized using a set of sieves, with diameter ranges and limits determined by the selected mesh openings. As an alternative to sieving, the roller technique uses rotating sloped rollers with a diverging gap to size classify particles. Particles are fed onto the gap between the rollers. The rollers are tilted or angled downward away from the feed point to create an inclined track. The rollers rotate with an upward and outward motion. A particle travels down the gradually widening gap until it reaches a point equal to its diameter upon which it drops through the gap into a collection bin. The gap between the rollers is adjusted to separate different sizes of particles or to classify particles within a specific range of diameters. A schematic illustrating the relationship between roller gap and particle size is shown in Figure 4.1.

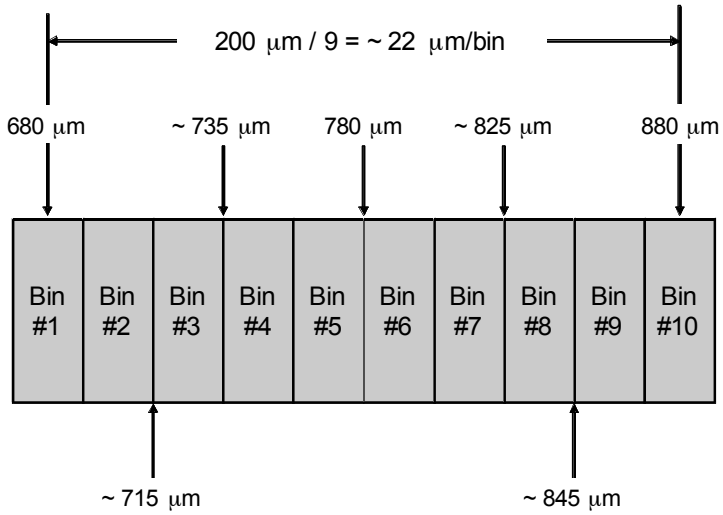


Figure 4.1. Schematic of the collection bins and roller spacing showing relationship between roller gap and particle size for LEU03-03T.

From EDF-6638, Rev 1, section 5.1.1, Sieving or Rolling to Remove Undersize and Oversize Particles, “each batch shall be double-sieved with electroformed sieves to remove all particles that pass through a 700 μm sieve and all particles that do not pass through an 850 μm sieve. . . . Alternately, the particles can be size-classified using a roller micrometer that achieves results equivalent to or better than sieving." To size separate the coated particles for batch LEU03-03T,

the gaps between the rollers above bins #1 and #10 were set at 680 and 880 μm, respectively, producing the size distribution shown in the figure. Only particles from Bins #6 - #8, with a nominal particle size range of 780 to 845 μm, were retained. To size separate the coated particles for LEU03-04T and LEU03-06T, the gaps between the rollers above bins #1 and #10 were set at 700 and 920 μm, respectively. Only particles from Bins #5 - #7, with a nominal particle size range of 786 to 859 μm, were retained. To size separate the coated particles for LEU03-05T, the gaps between the rollers above bins #1 and #10 were set at 700 and 840 μm, respectively. Only particles from Bins #7 - #10, with a nominal particle size range of 786 to 848 μm, were retained.

The following pages contain records of the classification performed on the TRISO-coated particle batches associated with the LEU03-09T coated particle composite.

TRISO batches

LEU03-03T (TRISO batch 1)
LEU03-04T (TRISO batch 2)
LEU03-05T (TRISO batch 3)
LEU03-06T (TRISO batch 4)

Sizing & Removal of Aspherical Particles for LEU03-03T

Summary for Sizing of Kernels or Coated Particles

Procedure:		AGR-ROLLER-SOP-01, Rev. 0		
Operator:		R. A. Lowden		
Kernel/Coated Particle ID:		LEU03-03T		
Kernel/Coated Particle Description:		Baseline, full TRISO on 350 μm LEUCO		
Data Location:		B002163, Sizing & Tabling, p. 73		
Date	Batch Weight (g)	Sized Batch Weight (g)	Scrap (g)	Loss (g)
08/30/2006	194.34	178.07	16.26	(0.01)
Comments:				
Operator:	Richard A Lowden	Date:	8/30/06	
QAS:	M. C. Thelen	Date:	2/28/07	

Summary for Tabling of Kernels or Coated Particles

Procedure:		AGR-TABLE-SOP-01, Rev. 1		
Operator:		R. A. Lowden		
Kernel/Coated Particle ID:		LEU03-03T		
Kernel/Coated Particle Description:		Baseline, full TRISO on 350 μm LEUCO		
Data Location:		B002163, Sizing & Tabling, p. 76		
Date	Batch Weight (g)	Tabled Batch Weight (g)	Scrap (g)	Loss (g)
09/06/2006	178.07	169.58	8.46	(0.03)
Comments:				
Operator:	Richard A Lowden	Date:	9/6/06	
QAS:	M. C. Thelen	Date:	2/28/07	

Sizing & Removal of Aspherical Particles for LEU03-04T

Summary for Sizing of Kernels or Coated Particles

Procedure:		AGR-ROLLER-SOP-01, Rev. 0		
Operator:		R. A. Lowden		
Kernel/Coated Particle ID:		LEU03-04T		
Kernel/Coated Particle Description:		Baseline, full TRISO on 350 μm LEUCO		
Data Location:		B002163, Sizing & Tabling, p. 74		
Date	Batch Weight (g)	Sized Batch Weight (g)	Scrap (g)	Loss (g)
09/01/2006	190.54	180.05	10.50	+0.01
Comments:				
Operator:	Richard A Lowden		Date:	9/1/06
QAS:	M. C. Fern		Date:	2/28/07

Summary for Tabling of Kernels or Coated Particles

Procedure:		AGR-TABLE-SOP-01, Rev. 1		
Operator:		R. A. Lowden		
Kernel/Coated Particle ID:		LEU03-04T		
Kernel/Coated Particle Description:		Baseline, full TRISO on 350 μm LEUCO		
Data Location:		B002163, Sizing & Tabling, p. 77		
Date	Batch Weight (g)	Tabled Batch Weight (g)	Scrap (g)	Loss (g)
09/06/2006	180.05	172.16	7.87	(0.02)
Comments:				
Operator:	Richard A Lowden		Date:	9/6/06
QAS:	M. C. Fern		Date:	2/28/07

Sizing & Removal of Aspherical Particles for LEU03-05T

Summary for Sizing of Kernels or Coated Particles

Procedure:		AGR-ROLLER-SOP-01, Rev. 0		
Operator:		R. A. Lowden		
Kernel/Coated Particle ID:		LEU03-05T		
Kernel/Coated Particle Description:		Baseline, full TRISO on 350 μm LEUCO		
Data Location:		B002163, Sizing & Tabling, pp. 75,80		
Date	Batch Weight (g)	Sized Batch Weight (g)	Scrap (g)	Loss (g)
10/06/2006	192.66	182.89	9.77	0.00
Comments: First rolled on 9/06/2006, re-rolled on 10/06/2006 to remove small particles. Combined results shown.				
Operator:	Richard A Lowden		Date:	10/6/06
QAS:	M. C. Lee		Date:	2/28/07

Summary for Tabling of Kernels or Coated Particles

Procedure:		AGR-TABLE-SOP-01, Rev. 1		
Operator:		R. A. Lowden		
Kernel/Coated Particle ID:		LEU03-05T		
Kernel/Coated Particle Description:		Baseline, full TRISO on 350 μm LEUCO		
Data Location:		B002163, Sizing & Tabling, p. 81		
Date	Batch Weight (g)	Tabled Batch Weight (g)	Scrap (g)	Loss (g)
10/12/2006	182.89	170.83	12.04	(0.02)
Comments:				
Operator:	Richard A Lowden		Date:	10/12/06
QAS:	M. C. Lee		Date:	2/28/07

Sizing & Removal of Aspherical Particles for LEU03-06T

Summary for Sizing of Kernels or Coated Particles

Procedure:				AGR-ROLLER-SOP-01, Rev. 0
Operator:				R. A. Lowden
Kernel/Coated Particle ID:				LEU03-06T
Kernel/Coated Particle Description:				Baseline, full TRISO on 350 μm LEUCO
Data Location:				B002163, Sizing & Tabling, p. 78
Date	Batch Weight (g)	Sized Batch Weight (g)	Scrap (g)	Loss (g)
09/07/2006	190.84	181.14	9.68	(0.02)
Comments:				
Operator:	Richard A Lowden		Date:	9/7/06
QAS:	M. C. Thompson		Date:	3/2/07

Summary for Tabling of Kernels or Coated Particles

Procedure:				AGR-TABLE-SOP-01, Rev. 1
Operator:				R. A. Lowden
Kernel/Coated Particle ID:				LEU03-05T
Kernel/Coated Particle Description:				Baseline, full TRISO on 350 μm LEUCO
Data Location:				B002163, Sizing & Tabling, p. 79
Date	Batch Weight (g)	Tabled Batch Weight (g)	Scrap (g)	Loss (g)
10/05/2006	181.14	172.16	8.95	(0.03)
Comments:				
Operator:	Richard A Lowden		Date:	10/5/06
QAS:	M. C. Thompson		Date:	3/2/07

5 Blend of coated particle composites

Four batches of TRISO-coated particles were blended into composite LEU03-09T. The mass of each batch added to the composite is shown in the following table.

Batch ID	Amount added to LEU03-09T composite (g)
LEU03-03T	150.0875
LEU03-04T	152.8221
LEU03-05T	151.1892
LEU03-06T	152.4734
Total	606.5722

Three batches of buffer-coated particles were blended into composite NUCO350-58B. The mass of each batch added to the composite is shown in the following table.

Batch ID	Amount added to NUCO350-58B composite (g)
NUCO350-25B	54.4356
NUCO350-36B	55.8622
NUCO350-54B	56.0934
Total	166.3912

Three batches of buffer/IPyC-coated particles were blended into composite NUCO350-66BI. The mass of each batch added to the composite is shown in the following table.

Batch ID	Amount added to NUCO350-66BI composite (g)
NUCO350-30BI	96.9421
NUCO350-37BI	96.1568
NUCO350-29BI	98.2502
Total	291.3491

6 Characterization of LEU03 kernel composite

This section contains data on the kernel composite used for LEU03-09T. The data was obtained according to product inspection plan AGR-CHAR-PIP-01R1. This is only a partial analysis of the kernel composite and was not used for product acceptance. Characterization of the kernel composite for acceptance according to the specific requirements listed in section 4 of INL EDF-6638 is documented in the BWXT data package for G73V-20-69303. The BWXT kernel lot G73V-20-69303 was riffled into sublots for characterization and coating by ORNL and identified as LEU03-## (where ## is a series of integers beginning with 01).

The following pages shows the inspection report form (IRF-01). Following IRF-01 are the individual data report forms for the measurements that were performed.

Inspection Report Form IRF-01: BWXT LEUCO Kernel Composite 69303

Procedure: AGR-CHAR-PIP-01 Rev. 1

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	k or t value	INL EDF-4380			
Average kernel diameter (µm)	357.3	10.5	3847	1.65	mean 350 ± 10	A = x - ts/√n ≥ 340	357.0	DRF-06 DRF-09
						B = x + ts/√n ≤ 360	357.6	
				2.38	dispersion ≤0.01 < 300 ≤0.01 > 400	C = x - ks > 300	332.3	
						D = x + ks < 400	382.3	
Kernel ellipticity (Dmax/Dmin)	1.016		3847		dispersion ≤0.10 ≥1.05	≤1 in 50 or ≤7 in 142	11	DRF-06 DRF-09
Kernel envelope density (Mg/m^3)	11.098	0.025	3	2.920	mean ≥10.4	A = x - ts/√n ≥ 10.4	11.1	DRF-15 DRF-22

Comments

11 kernels with ellipticity ≥1.05 out of 3847 kernels measured passes the dispersion specification acceptance criteria of ≤353 in 3847.
This composite would pass a control limit of ≥1.026 at 10% tolerance limit with 95% confidence level.
This composite would pass a control limit of ≥1.05 at 0.48% tolerance limit with 95% confidence level.

QC Supervisor — Date: 2-20-07

QA Reviewer — Date: 2/20/07

Data Report Form DRF-06: Imaging of Kernel Diameter and Ellipticity Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-06 Rev. 1
Operator:	Andrew K. Kercher
Sample ID:	LEU03-01K-B01
Sample Description:	BWXT kernel composite 69303
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P06080902\

DMR Calibration Expiration Date:	9/8/2006
Stage Micrometer Calibration Expiration Date:	2/17/2007
Measured Value for 760 µm in Stage Micrometer Image:	759.4 µm

Andrew K. Kercher — August 9, 2006

Operator — Date

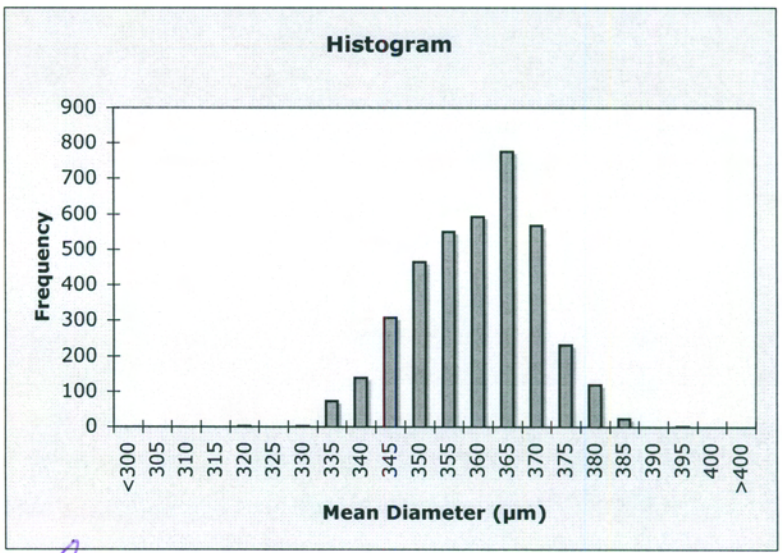
Data Report Form DRF-09A: Measurement of Kernel Diameter

Procedure:	AGR-CHAR-DAM-09 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P06080902\
Sample ID:	LEU03-01K-B01
Sample Description:	BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P06080902_output\

Number of kernels analyzed:	3847
Mean of the average diameter of each kernel (μm):	357.3
Standard deviation in the average diameter of each kernel (μm):	10.5

Distribution of the average particle diameter (top binned)

Mean Diameter (μm)	*Frequency*
<300	0
305	0
310	0
315	0
320	1
325	0
330	2
335	73
340	138
345	308
350	465
355	550
360	592
365	775
370	567
375	232
380	120
385	23
390	0
395	1
400	0
>400	0



Andrew K. Kercher
Operator

August 10, 2006
Date

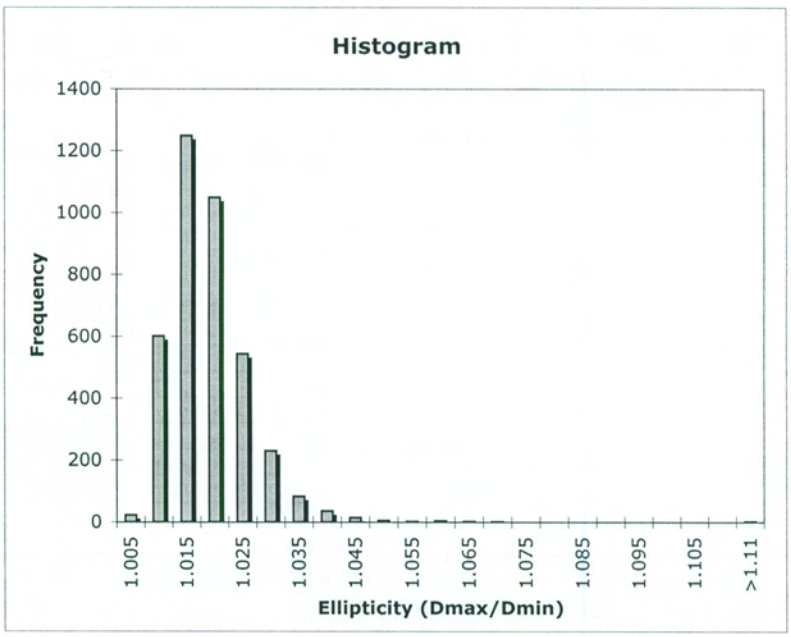
Data Report Form DRF-09B: Measurement of Kernel Ellipticity (Dmax/Dmin)

Procedure:	AGR-CHAR-DAM-09 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P06080902\
Sample ID:	LEU03-01K-B01
Sample Description:	BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P06080902_output\

Number of kernels analyzed:	3847
Number of kernels with ellipticity > 1.05	11
Average kernel ellipticity:	1.016

Distribution of the ellipticity (top binned)

Ellipticity (D)	*Frequency*
1.005	23
1.010	602
1.015	1249
1.020	1049
1.025	544
1.030	230
1.035	83
1.040	36
1.045	15
1.050	5
1.055	2
1.060	4
1.065	2
1.070	1
1.075	0
1.080	0
1.085	0
1.090	0
1.095	0
1.100	0
1.105	0
1.110	0
>1.11	2



Operator

August 10, 2006

Date

Data Report Form DRF-15: Measurement of Average Kernel Envelope Density using a Mercury Porosimeter

Procedure:	AGR-CHAR-DAM-15 Rev. 3
Operator:	S. D. Nunn
Kernel Lot ID:	LEU03-01K
Kernel Lot Description:	BWXT kernel composite 69303
Thermocouple Expiration Date:	5/19/07
Penetrometer Expiration Date:	5/25/07
Completed DRF Filename:	\\mc-agr\AGR\Porosimeter\S06081001\S06081001_DRF15R3.xls

Mean average weight/kernel (g):	2.628E-04
Standard error in mean average weight/kernel (g):	8.48E-07

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Porosimeter data file number:	S06081001L	S06081002L	S06081003L		
Weight of kernels (g):	12.7870	12.8001	12.7347		
Approximate number of kernels:	48657	48707	48458		
Uncertainty in number of kernels:	157	157	156		
Envelope volume of sample (cc):	1.1502	1.1563	1.1467		
Average envelope volume/kernel (cc):	2.36E-05	2.37E-05	2.37E-05		
Sample envelope density (g/cc):	11.117	11.070	11.106		

Mean average envelope volume/kernel (cc):	2.368E-05
Standard error in mean envelope volume/kernel (cc):	3.0E-08
Mean sample envelope density (g/cc):	11.098
Standard deviation in sample envelope density (g/cc):	0.025

Comments
Only 3 samples were measured due to the limited amount of kernels available for AGR-3/4 fabrication.

S. D. Nunn
Operator

8/15/06
Date

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	John Hunn
Particle Lot ID:	LEU03-01K
Particle Lot Description:	BWXT kernel composite 69303
Filename:	\\mc-agr\AGR\ParticleWeight\W06080901_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	6.15E-02	7.35E-02	6.83E-02	6.50E-02	6.68E-02
Number of particles:	236	279	259	249	252
Average weight/particle (g):	2.61E-04	2.63E-04	2.64E-04	2.61E-04	2.65E-04

Mean average weight/particle (g):	2.628E-04
Standard error in mean average weight/particle (g):	8.48E-07

John Hunn
Operator

8-9-06
Date

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	Dixie Barker
Particle Lot ID:	LEU03-01K
Particle Lot Description:	BWXT kernel composite 69303
Filename:	\\mc-agr\AGR\ParticleWeight\W06080902_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	6.15E-02	7.35E-02	6.83E-02	6.50E-02	6.68E-02
Number of particles:	236	278	259	250	252
Average weight/particle (g):	2.61E-04	2.64E-04	2.64E-04	2.60E-04	2.65E-04

Mean average weight/particle (g):	2.628E-04
Standard error in mean average weight/particle (g):	1.03E-06

Dixie Barker
Operator

8-9-06
Date

8 Characterization of LEU01 kernel composite

This section contains data on the kernel composite used for LEU01-16B and LEU01-15I. These were interrupted coated particle batches characterized to confirm the buffer and IPyC process qualification results. The data was obtained according to product inspection plan AGR-CHAR-PIP-01R1. Some of the kernel data in this section was used as input for subsequent measurements of coating properties (e.g., buffer density). This is only a partial analysis of the kernel composite and was not used for product acceptance. Characterization of the kernel composite for acceptance according to the specific requirements listed in section 4 of INL EDF-4380, is documented in the BWXT data package for G73D-20-69302. The BWXT kernel lot G73D-20-69302 was riffled into sublots for characterization and coating. The ORNL identification for these kernels was LEU01-## (where ## were a series of integers beginning with 01).

The following pages shows the inspection report form (IRF-01). Following IRF-01 are the individual data report forms for the measurements that were performed.

Inspection Report Form IRF-01: BWXT NUCO Kernel Composite 69300

Procedure: AGR-CHAR-PIP-01 Rev. 1

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	k or t value	INL EDF-4380 Rev. 4			
Average kernel diameter (μm)	344.9	15	4202	1.645	mean 350 ± 10	A = x - ts/√n ≥ 340	344.5	DRF-06 DRF-09
						B = x + ts/√n ≤ 360	345.3	
				2.38	dispersion ≤0.01 < 300 ≤0.01 > 400	C = x - ks > 300	309.2	
						D = x + ks < 400	380.6	
Kernel ellipticity (Dmax/Dmin)	1.022		4202		dispersion ≤0.10 ≥1.05	≤1 in 50 or ≤7 in 142	186	DRF-06 DRF-09
Kernel envelope density (Mg/m^3)	10.800	0.006	5	2.132	mean ≥10.4	A = x - ts/√n ≥ 10.4	10.79	DRF-15 DRF-22

Comments

186 kernels with ellipticity ≥1.05 out of 4202 kernels measured passes the dispersion specification acceptance criteria of ≤387 in 4202.
This composite would pass an ellipticity control limit of ≥1.038 at 10% tolerance limit with 95% confidence level.
This composite would pass an ellipticity control limit of ≥1.05 at 5% tolerance limit with 95% confidence level.

QC Supervisor — Date: 2-20-06

QA Reviewer — Date: 2/22/06

Data Report Form DRF-06: Imaging of Kernel Diameter and Ellipticity Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-06 Rev. 0
Operator:	Andrew Nelson
Sample ID:	NUCO350-26B
Sample Description:	350 um NUCO kernels from BWXT 69300 Composite
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P05052501

DMR Calibration Expiration Date:	3/25/06
Stage Micrometer Calibration Expiration Date:	2/17/07
Measured Value for 760 µm in Stage Micrometer Image:	760.6 µm

Mean average weight/particle (g):	~~2.39E-04~~	2.31E-04	4-17-06
Weight of sample of particles (g):	1.408		
Approximate number of particles in sample:	~~5891~~	6095	4-17-06

Operator	Date
	5/25/2005

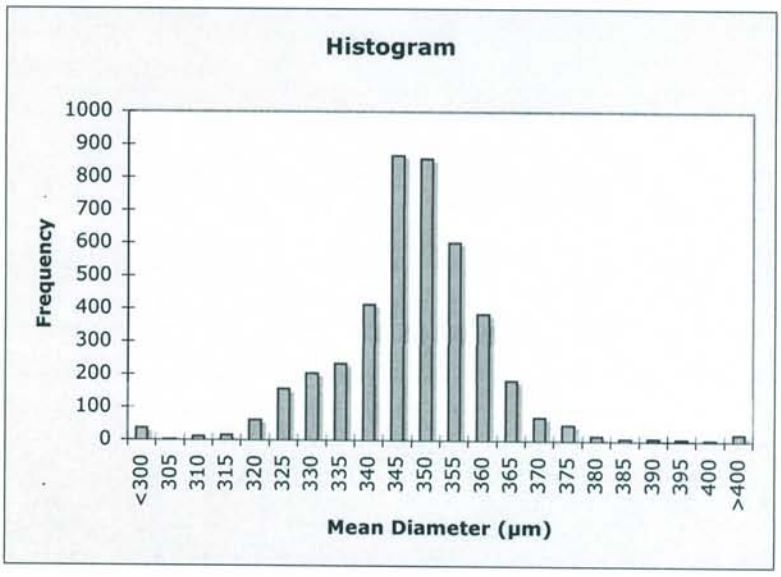
Data Report Form DRF-09A: Measurement of Kernel Diameter

Procedure:	AGR-CHAR-DAM-09 Rev. 0
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P05052501
Sample ID:	NUCO350-26B NUCO kernels
Sample Description:	350 um NUCO kernels from BWXT 69300 Composite
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P05052501_output

Number of kernels analyzed:	4202
Mean of the average diameter of each kernel (μm):	344.9
Standard deviation in the average diameter of each kernel (μm):	15

Distribution of the average kernel diameter (top binned)

Mean Diameter	*Frequency*
<300	36
305	1
310	11
315	15
320	61
325	156
330	204
335	233
340	412
345	867
350	858
355	603
360	383
365	182
370	71
375	48
380	16
385	8
390	7
395	5
400	3
>400	22



Andrew K. Kercher
Operator

May 31, 2005
Date

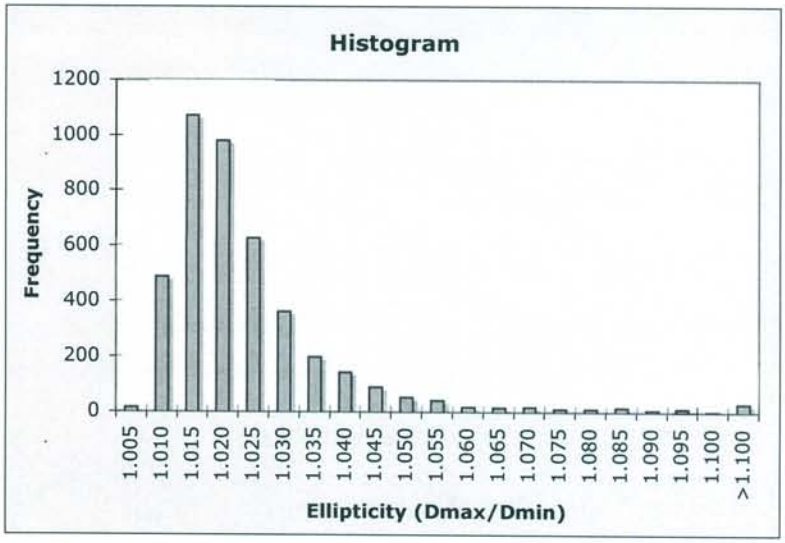
Data Report Form DRF-09B: Measurement of Kernel Ellipticity (Dmax/Dmin)

Procedure:	AGR-CHAR-DAM-09 Rev. 0
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P05052501
Sample ID:	NUCO350-26B NUCO kernels
Sample Description:	350 um NUCO kernels from BWXT 69300 Composite
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P05052501_output

Number of kernels analyzed:	4202
Number of kernels with ellipticity >1.05:	186
Average kernel ellipticity:	1.022

Distribution of the ellipticity (top binned)

Ellipticity (D)	*Frequency*
1.005	15
1.010	486
1.015	1069
1.020	979
1.025	627
1.030	361
1.035	197
1.040	141
1.045	89
1.050	52
1.055	42
1.060	19
1.065	17
1.070	19
1.075	11
1.080	12
1.085	15
1.090	8
1.095	11
1.100	2
>1.100	30



A. K. Kercher
Operator

May 31, 2005
Date

Data Report Form DRF-15: Measurement of Average Kernel Envelope Density using a Mercury Porosimeter

Procedure:	AGR-CHAR-DAM-15 Rev. 2
Operator:	S. D. NUNN
Kernel Lot ID:	NUCO350-26
Kernel Lot Description:	NUCO KERNEL COMPOSITE 69300
Thermocouple Expiration Date:	5/23/06
Penetrometer Expiration Date:	5/25/06
Completed DRF Filename:	\\mc-agr\AGR\Porosimeter\S05052601\S05052601R1_DRF15R2

Mean average weight/kernel (g):	2.31E-04
Uncertainty in mean average weight/kernel (g):	8.69E-07

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Porosimeter data file number:	S05052601L	S0502602L	S05052603L	S05052604L	S05052605L
Weight of kernels (g):	12.8272	12.9542	12.9410	12.9793	12.9624
Approximate number of kernels:	55577	56127	56070	56236	56163
Uncertainty in number of kernels:	209	211	211	212	211
Envelope volume of sample (cc):	1.187	1.200	1.199	1.202	1.199
Average envelope volume/kernel (cc):	2.14E-05	2.14E-05	2.14E-05	2.14E-05	2.14E-05
Sample envelope density (g/cc):	10.805	10.792	10.797	10.799	10.807

Mean average envelope volume/kernel (cc):	2.137E-05
Uncertainty in mean envelope volume/kernel (cc):	5.47E-09
Mean sample envelope density (g/cc):	10.800
Standard deviation in sample envelope density (g/cc):	0.006

S. D. Nunn
Operator

2/14/06
Date

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	John Hunn
Particle Lot ID:	NUCO350-42-A
Particle Lot Description:	BWXT kernel composite 69300
Filename:	\\mc-agr\AGR\ParticleWeight\W06020302_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	3.13E-02	2.84E-02	3.40E-02	3.48E-02	3.40E-02
Number of particles:	136	123	149	149	147
Average weight/particle (g):	2.30E-04	2.31E-04	2.28E-04	2.34E-04	2.31E-04

Mean average weight/particle (g):	2.308E-04
Uncertainty in mean average weight/particle (g):	8.69E-07

John Hunn
Operator

2-3-06
Date

8 Characterization of LEU01 kernel composite

This section contains data on the kernel composite used for LEU01-16B and LEU01-15I. These were interrupted coated particle batches characterized to confirm the buffer and IPyC process qualification results. The data was obtained according to product inspection plan AGR-CHAR-PIP-01R1. Some of the kernel data in this section was used as input for subsequent measurements of coating properties (e.g., buffer density). This is only a partial analysis of the kernel composite and was not used for product acceptance. Characterization of the kernel composite for acceptance according to the specific requirements listed in section 4 of INL EDF-4380, is documented in the BWXT data package for G73D-20-69302. The BWXT kernel lot G73D-20-69302 was riffled into sublots for characterization and coating. The ORNL identification for these kernels was LEU01-## (where ## were a series of integers beginning with 01).

The following pages shows the inspection report form (IRF-01). Following IRF-01 are the individual data report forms for the measurements that were performed.

Inspection Report Form IRF-01: BWXT LEUCO Kernel Composite 69302

Procedure:	AGR-CHAR-PIP-01 Rev. 1

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	k or t value	INL EDF-4380 Rev. 6			
Average kernel diameter (μm)	349.7	9	4304	1.645	mean 350 ± 10	A = x - ts/√n ≥ 340	349.5	DRF-06 DRF-09
						B = x + ts/√n ≤ 360	349.9	
				2.38	dispersion ≤0.01 < 300 ≤0.01 > 400	C = x - ks > 300	328.3	
						D = x + ks < 400	371.1	
Kernel ellipticity (Dmax/Dmin)	1.021		4304		dispersion ≤0.10 ≥1.05	≤1 in 50 or ≤7 in 142	94	DRF-06 DRF-09
Kernel envelope density (Mg/m³)	10.924	0.015	5	2.132	mean ≥10.4	A = x - ts/√n ≥ 10.4	10.91	DRF-15 DRF-22

Comments

94 kernels with ellipticity ≥1.05 out of 4304 kernels measured passes the dispersion specification acceptance criteria of ≤397 in 4304.
This composite would pass a control limit of ≥1.035 at 10% tolerance limit with 95% confidence level.
This composite would pass a control limit of ≥1.05 at 2.6% tolerance limit with 95% confidence level.

QC Supervisor — Date: 2-16-06

QA Reviewer — Date: 3/29/06

Data Report Form DRF-06: Imaging of Kernel Diameter and Ellipticity Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-06 Rev. 0
Operator:	Andrew Kercher
Sample ID:	~~LEUCO350-01B~~ renamed LEU01-01K-B JH 4-17-06
Sample Description:	LEUCO kernel composite 69302
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P05051902\

DMR Calibration Expiration Date:	3/24/06
Stage Micrometer Calibration Expiration Date:	2/17/07
Measured Value for 760 µm in Stage Micrometer Image:	760. µm

Mean average weight/particle (g):	~~2.47E-04~~ 2.42E-04 JH 3-22-06
Weight of sample of particles (g):	1.519
Approximate number of particles in sample:	~~6150~~ 6277 JH 3-22-06

Richard L. Kercher — **Operator**

05/19/05 — **Date**

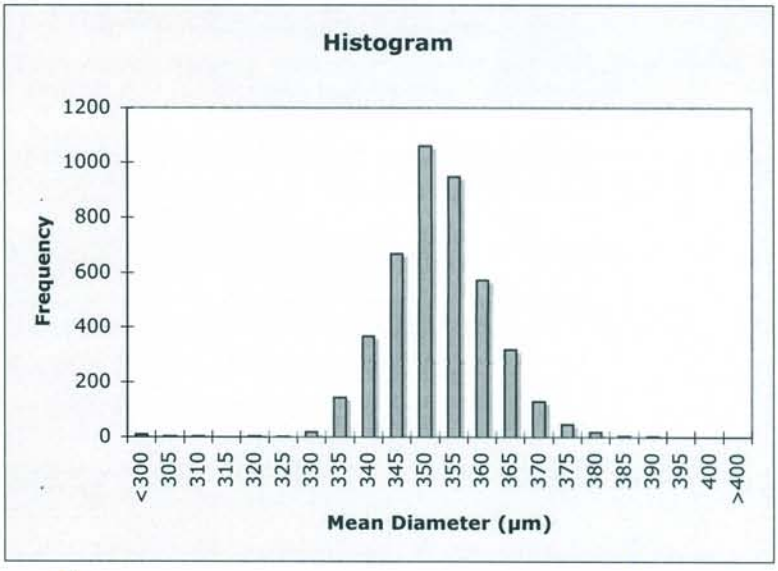
Data Report Form DRF-09A: Measurement of Kernel Diameter

Procedure:	AGR-CHAR-DAM-09 Rev. 0
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P05051902
Sample ID:	~~LEUCO350-01B~~ renamed LEU01-01K-B 4-17-06
Sample Description:	BWXT LEUCO kernel composite 69302
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P05051902_output

Number of kernels analyzed:	4304
Mean of the average diameter of each kernel (µm):	349.7
Standard deviation in the average diameter of each kernel (µm):	9

Distribution of the average kernel diameter (top binned)

Mean Diameter	*Frequency*
<300	9
305	2
310	2
315	1
320	2
325	2
330	18
335	143
340	366
345	666
350	1060
355	946
360	572
365	317
370	128
375	45
380	18
385	4
390	3
395	0
400	0
>400	0



Andrew K. Kercher
Operator

May 23, 2005
Date

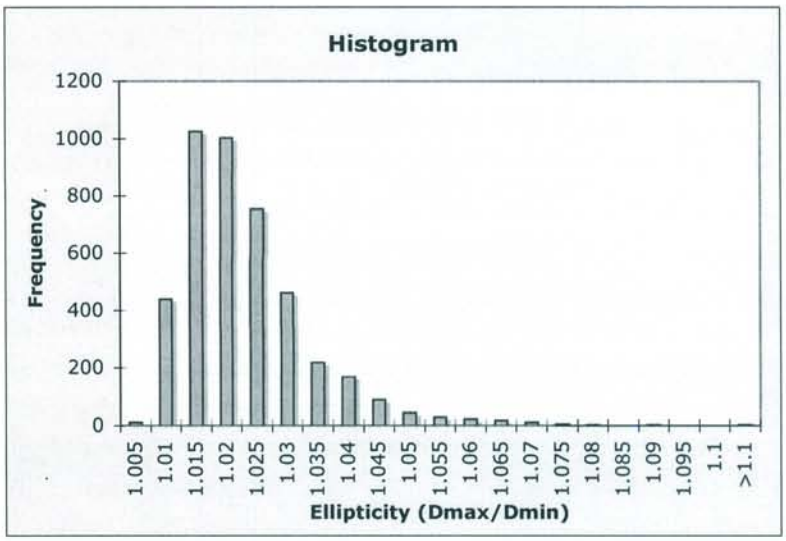
Data Report Form DRF-09B: Measurement of Kernel Ellipticity (Dmax/Dmin)

Procedure:	AGR-CHAR-DAM-09 Rev. 0
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P05051902
Sample ID:	~~LEUCO350-01B~~ renamed LEU01-01K-B AK 4-17-06
Sample Description:	BWXT LEUCO kernel composite 69302
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P05051902_output

Number of kernels analyzed:	4304
Number of kernels with ellipticity >1.05:	94
Average kernel ellipticity:	1.021

Distribution of the ellipticity (top binned)

Ellipticity (D)	*Frequency*
1.005	10
1.01	439
1.015	1025
1.02	1003
1.025	754
1.03	462
1.035	218
1.04	166
1.045	89
1.05	44
1.055	29
1.06	21
1.065	17
1.07	12
1.075	5
1.08	3
1.085	1
1.09	2
1.095	0
1.1	1
>1.1	3



Andrew K. Kercher
Operator

May 23, 2005
Date

Data Report Form DRF-15: Measurement of Average Kernel Envelope Density using a Mercury Porosimeter

Procedure:	AGR-CHAR-DAM-15 Rev. 2
Operator:	S. D. NUNN
Kernel Lot ID:	~~LEUCO350-01~~ renamed LEU01-01 K 4-17-06
Kernel Lot Description:	BWXT LEUCO KERNEL COMPOSITE 69302
Thermocouple Expiration Date:	5/23/06
Penetrometer Expiration Date:	5/25/06
Completed DRF Filename:	\\mc-agr\AGR\Porosimeter\S05052701\S05052701R1_DRF15R2

Mean average weight/kernel (g):	2.42E-04
Uncertainty in mean average weight/kernel (g):	5.96E-07

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Porosimeter data file number:	S05052701L	S05052702L	S05052703L	S05052704L	S05052705L
Weight of kernels (g):	12.5822	12.5075	12.8773	12.6448	12.6895
Approximate number of kernels:	52036	51727	53256	52294	52479
Uncertainty in number of kernels:	128	128	131	129	129
Envelope volume of sample (cc):	1.150	1.145	1.180	1.157	1.164
Average envelope volume/kernel (cc):	2.21E-05	2.21E-05	2.22E-05	2.21E-05	2.22E-05
Sample envelope density (g/cc):	10.943	10.925	10.912	10.932	10.906

Mean average envelope volume/kernel (cc):	2.214E-05
Uncertainty in mean envelope volume/kernel (cc):	1.34E-08
Mean sample envelope density (g/cc):	10.924
Standard deviation in sample envelope density (g/cc):	0.015

S. D. Nunn — Operator

2/14/06 — Date

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	John Hunn
Particle Lot ID:	LEU01-32K-A
Particle Lot Description:	BWXT kernel composite 69302
Filename:	\\mc-agr\AGR\ParticleWeight\W06020601_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	5.76E-02	5.33E-02	5.20E-02	4.90E-02	4.85E-02
Number of particles:	239	220	215	204	199
Average weight/particle (g):	2.41E-04	2.42E-04	2.42E-04	2.40E-04	2.44E-04

Mean average weight/particle (g):	2.418E-04
Uncertainty in mean average weight/particle (g):	5.96E-07

John Hunn
Operator

2-6-06
Date

9 Characterization of DUN350 kernel composite

This section contains data on the kernel composite used for DUN350-19B. This was an interrupted coated particle batch characterized to confirm the buffer process qualification results. The data was obtained according to product inspection plan AGR-CHAR-PIP-01R1. Some of the kernel data in this section was used as input for subsequent measurements of coating properties (e.g., buffer density). The ORNL identification for these kernels was DUN350-## (where ## were a series of integers beginning with 01).

The following pages shows the inspection report form (IRF-01). Following IRF-01 are the individual data report forms for the measurements that were performed.

Inspection Report Form IRF-01: ORNL DUN350 Kernel Composite

Procedure: AGR-CHAR-PIP-01 Rev. 1

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	k or t value	INL EDF-4380			
Average kernel diameter (µm)	354.1	4	4132	1.645	mean 350 ± 10	A = x - ts/√n ≥ 340	354.0	DRF-06 DRF-09
						B = x + ts/√n ≤ 360	354.2	
				2.376	dispersion ≤0.01 < 300 ≤0.01 > 400	C = x - ks > 300	344.6	
						D = x + ks < 400	363.6	
Kernel ellipticity (Dmax/Dmin)	1.007		4132		dispersion ≤0.10 ≥1.05	≤1 in 50 or ≤7 in 142	11	DRF-06 DRF-09
Kernel envelope density (Mg/m³)	10.877	0.025	3	2.920	mean ≥10.4	A = x - ts/√n ≥ 10.4	10.8	DRF-15 DRF-22

Comments

11 kernels with ellipticity ≥1.05 out of 4132 kernels measured passes the dispersion specification acceptance criteria of ≤381 in 4132.
This composite would pass a control limit of ≥1.012 at 10% tolerance limit with 95% confidence level.
This composite would pass a control limit of ≥1.05 at 0.45% tolerance limit with 95% confidence level.

QC Supervisor — Date: 2-20-07

QA Reviewer — Date: 2/20/07

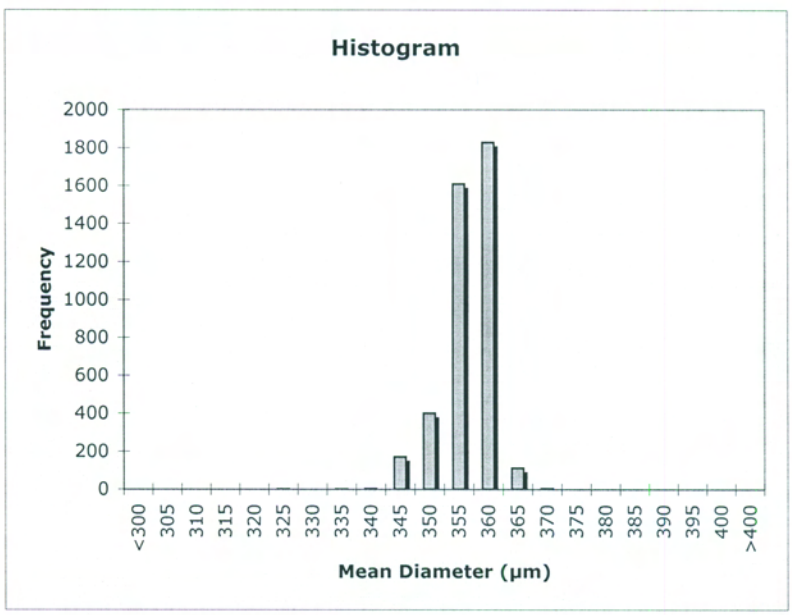
Data Report Form DRF-09A: Measurement of Kernel Diameter

Procedure:	AGR-CHAR-DAM-09 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P04051901_03\
Sample ID:	DUN350-1-8
Sample Description:	Depleted uranium oxide kernels
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P04051901_03_output\

Number of kernels analyzed:	4132
Mean of the average diameter of each kernel (μm):	354.1
Standard deviation in the average diameter of each kernel (μm):	4

Distribution of the average particle diameter (top binned)

Mean Diameter (μm)	*Frequency*
<300	0
305	0
310	0
315	0
320	0
325	1
330	0
335	1
340	3
345	171
350	401
355	1609
360	1830
365	112
370	4
375	0
380	0
385	0
390	0
395	0
400	0
>400	0



Operator

September 5, 2006

Date

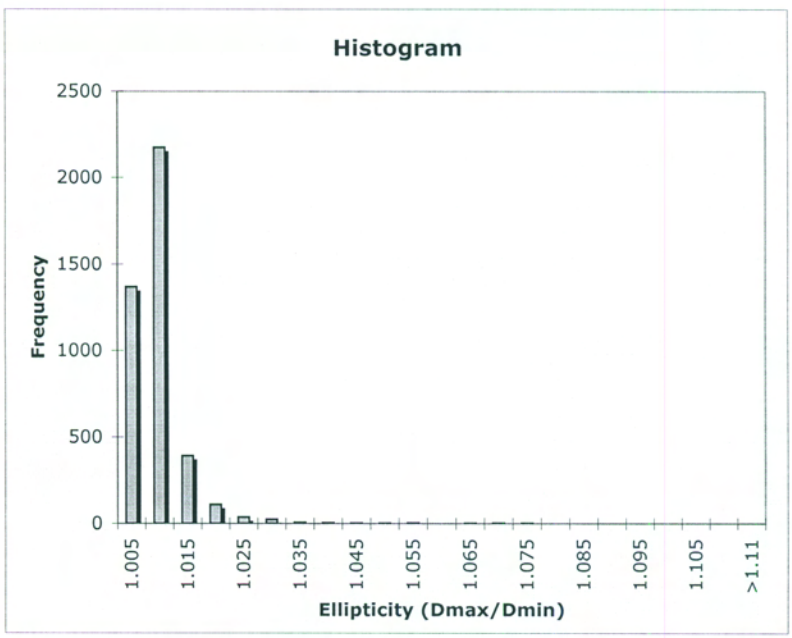
Data Report Form DRF-09B: Measurement of Kernel Ellipticity (Dmax/Dmin)

Procedure:	AGR-CHAR-DAM-09 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P04051901_03\
Sample ID:	DUN350-1-8
Sample Description:	Depleted uranium oxide kernels
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P04051901_03_output\

Number of kernels analyzed:	4132
Number of kernels with ellipticity > 1.05	11
Average kernel ellipticity:	1.007

Distribution of the ellipticity (top binned)

Ellipticity (D)	*Frequency*
1.005	1369
1.010	2174
1.015	391
1.020	109
1.025	37
1.030	25
1.035	6
1.040	5
1.045	3
1.050	2
1.055	4
1.060	0
1.065	2
1.070	3
1.075	2
1.080	0
1.085	0
1.090	0
1.095	0
1.100	0
1.105	0
1.110	0
>1.11	0



Operator

September 5, 2006
Date

Data Report Form DRF-15: Measurement of Average Kernel Envelope Density using a Mercury Porosimeter

Procedure:	AGR-CHAR-DAM-15 Rev. 3
Operator:	S. D. Nunn
Kernel Lot ID:	DUN350-13K and DUN350-34K
Kernel Lot Description:	Depleated uranium kernels
Thermocouple Expiration Date:	5/19/07
Penetrometer Expiration Date:	5/25/07
Completed DRF Filename:	\\mc-agr\AGR\Porosimeter\S06082301\S06082301_DRF15R3.xls

Mean average weight/kernel (g):	2.51E-04
Standard error in mean average weight/kernel (g):	1.33E-06

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Porosimeter data file number:	S05121501	S06082302	S06082303		
Weight of kernels (g):	12.7305	12.9157	12.9727		
Approximate number of kernels:	50719	51457	51684		
Uncertainty in number of kernels:	269	273	274		
Envelope volume of sample (cc):	1.169	1.191	1.192		
Average envelope volume/kernel (cc):	2.30E-05	2.31E-05	2.31E-05		
Sample envelope density (g/cc):	10.894	10.848	10.888		

Mean average envelope volume/kernel (cc):	2.308E-05
Standard error in mean envelope volume/kernel (cc):	3.0E-08
Mean sample envelope density (g/cc):	10.877
Standard deviation in sample envelope density (g/cc):	0.025

Comments
First kernel sample discarded due to Hg cell leak. Sample 1 comes from DUN350-34K S05121501_DRF15R2.xls

S. D. Nunn — Operator

8/23/06 — Date

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	Dixie Barker
Particle Lot ID:	DUN350-33-H01
Particle Lot Description:	Depleted uranium oxide kernels
Filename:	\\mc-agr\AGR\ParticleWeight\W05122001_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	6.58E-02	6.54E-02	7.11E-02	6.71E-02	7.56E-02
Number of particles:	264	258	279	271	301
Average weight/particle (g):	2.49E-04	2.53E-04	2.55E-04	2.48E-04	2.51E-04

Mean average weight/particle (g):	2.51E-04
Uncertainty in mean average weight/particle (g):	1.33E-06

Dixie Barker
Operator

12-20-05
Date

10 Characterization of buffer on interrupted batches

This section contains data on the buffer coating envelope density and other buffer properties for particles removed from the coater after deposition of only the buffer layer. The buffer density data from these interrupted coating runs was originally used to qualify the AGR-1 baseline coating process for the buffer density. The data was obtained according to product inspection plan AGR-CHAR-PIP-02R4. Envelope density values had to be obtained from these interrupted batches because it is not feasible to measure the buffer density after all coating layers are applied. According to section 5.3 of the AGR-1 Fuel Product Specification and Characterization Guidance (EDF-4380, Rev. 6), three representative buffer layers from interrupted batches which met the specification for buffer density were sufficient to qualify the process for buffer density. The qualifying batches used nominally 350 μm diameter natural uranium oxide/uranium carbide kernels (NUCO). The kernels were obtained from BWXT and were identified as composite G73B-NU-69300. The use of the NUCO surrogate kernels was not expected to significantly affect the density of the buffer. To check this assumption for the AGR-1 acceptance tests, a confirmatory batch using LEUCO kernels from composite G73D-20-69302 (LEU01) was coated and the measured density was found to be within the range predicted by the NUCO qualification batches.

According to section 5.3 of EDF-6638, Rev. 1, this data also constitutes buffer density acceptance for the AGR-3/4 driver fuel coating process, provided that the relative coating conditions are essentially the same. Table 10-1 compares the relevant coating conditions specified in section 5.3 of EDF-6638, Rev. 1. The average surface area of the kernel charge was calculated from the weight of the kernel charge for each batch, the average kernel weight, and the average kernel diameter (assuming a spherical kernel). The range for the batches in each series is given and all the values are equivalent, within the combined uncertainties of the particle weight, diameter, and shape. The other coating conditions were taken directly from the run sheets in section 3 and are identical, with the exception of a negligible difference in the AGR-3/4 TGF.

Table 10-1. Comparison of buffer coating conditions

	NUCO qualification batches	AGR-1 baseline batches	AGR-3/4 driver batches
Average surface area of kernel charge	1003.4-1005.7 cm^2	1003.8-1008.3 cm^2	1008.0-1009.1 cm^2
Buffer deposition temperature	1450°C	1450°C	1450°C
Buffer total gas flowrate (TGF)	8530 sccm	8530 sccm	8540 sccm
Buffer coating gas fraction (CGF)	$0.61 \frac{C_2H_2}{TGF}$	$0.61 \frac{C_2H_2}{TGF}$	$0.61 \frac{C_2H_2}{TGF}$

The AGR-1 baseline qualification and confirmation runs were fabricated over one year prior to the AGR-3/4 coating campaign. Therefore, prior to coating AGR-3/4 particles, a second confirmatory batch using depleted uranium oxide kernels from composite DUN350 was coated and characterized to verify that the buffer density was still within the expected range. The measured density of this batch was found to be within the range predicted by the NUCO qualification batches.

The following page shows the inspection report form (IRF-02A) for the AGR-1 NUCO qualification batches. Following IRF-02A are the individual data report forms for the measurements that were performed. Additional data at the end of this section is provided for information only. The process conditions used to deposit the buffer layer for the batches in the LEU03-09T composite were determined to produce a buffer density which satisfies the specifications in section 5.3 of EDF 6638, Rev. 1.

Inspection Report Form IRF-02A: Interrupted Coating Batches - Buffer Density

Procedure:	AGR-CHAR-PIP-02 Rev. 4
Batch 1 ID:	NUCO350-25B
Batch 1 description:	Buffer-coated BWXT kernel composite 69300
Batch 2 ID:	NUCO350-36B
Batch 2 description:	Buffer-coated BWXT kernel composite 69300
Batch 3 ID:	NUCO350-54B
Batch 3 description:	Buffer-coated BWXT kernel composite 69300

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	t value (t)	INL EDF-4380 Rev. 6				
Batch 1: Buffer envelope density (Mg/m^3)	1.08	0.04	5	2.132	mean 1.03 ± 0.15	A = x - ts/√n ≥ 0.88	1.04	pass	DRF-16 DRF-22
						B = x + ts/√n ≤ 1.18	1.12	pass	
Batch 2: Buffer envelope density (Mg/m^3)	1.11	0.05	5	2.132	mean 1.03 ± 0.15	A = x - ts/√n ≥ 0.88	1.06	pass	DRF-16 DRF-22
						B = x + ts/√n ≤ 1.18	1.16	pass	
Batch 3: Buffer envelope density (Mg/m^3)	1.11	0.04	5	2.132	mean 1.03 ± 0.15	A = x - ts/√n ≥ 0.88	1.07	pass	DRF-16 DRF-22
						B = x + ts/√n ≤ 1.18	1.15	pass	

Comments

Standard deviations are √5 times the uncertainties in buffer density (standard errors) reported on DRF-16.
Average thickness of buffer was 108 µm based on average envelope volume of 9.25E-5 cc (effective diameter of 561 µm) and average kernel diameter of 345 µm.
Average thickness of buffer was 108 µm based on average outer diameter of 561 µm obtained per DAM-10 and average kernel diameter of 345 µm.
Confirmatory batch on LEUCO kernels, LEU01-163: mean buffer density = 1.10 g/cc.

John Hunn — **QC Supervisor**

3-10-06 — **Date**

Accept process for buffer density (Yes or No):	Yes

QA Reviewer

3/29/06 — **Date**

Data Report Form DRF-16: Measurement of Buffer Envelope Density using a Mercury Porosimeter

Procedure:	AGR-CHAR-DAM-16 Rev. 2
Operator:	S. D. NUNN
Buffer-coated kernel batch ID:	NUCO350-25B
Batch Description:	Buffer Coated BWXT Kernel Composite 69300
Thermocouple Expiration Date:	5/23/06
Penetrometer Expiration Date:	5/25/06
Completed DRF Filename:	\\mc-agr\AGR\Porosimeter\S05062001\S05062001R1_DRF16R2.xls

Mean average weight/buffer-coated kernel (g):	3.07E-04
Uncertainty in mean average weight/b-c kernel (g):	1.00E-06
Mean average weight/bare kernel (g):	2.31E-04
Uncertainty in mean average weight/bare kernel (g):	8.69E-07
Mean average envelope volume/bare kernel (cc):	2.14E-05
Uncertainty in envelope volume/bare kernel (cc):	5.47E-09

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Porosimeter data file number:	S05062001L	S05062002L	S05062003L	S05062004L	S05062005L
Weight of buffer-coated kernels (g):	4.1223	4.2165	4.4333	4.4104	4.0445
Approximate number of b-c kernels:	13428	13735	14441	14366	13174
Uncertainty in number of b-c kernels:	44	45	47	47	43
Total envelope volume of sample (cc):	1.235	1.268	1.335	1.321	1.212
Av. envelope volume/b-c kernels (cc):	9.19E-05	9.23E-05	9.24E-05	9.19E-05	9.20E-05
Sample envelope density (g/cc):	3.339	3.326	3.321	3.340	3.338

Mean average envelope volume/b-c kernel (cc):	9.21E-05
Uncertainty in envelope volume/b-c kernel (cc):	1.1E-07

Buffer density:	1.08E+00
Uncertainty in buffer density:	1.88E-02

S. D. Nunn
Operator

2/14/06
Date

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	Dixie Barker
Particle Lot ID:	NUC0350-25B
Particle Lot Description:	Buffer Coated NUCO
Filename:	\\mc-agr\AGR\ParticleWeight\W05062001_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	3.28E-02	2.73E-02	3.08E-02	3.46E-02	3.99E-02
Number of particles:	107	90	100	113	129
Average weight/particle (g):	3.07E-04	3.03E-04	3.08E-04	3.06E-04	3.09E-04

Mean average weight/particle (g):	3.07E-04
Uncertainty in mean average weight/particle (g):	1.00E-06

Dixie Barker
Operator

6-20-05
Date

Data Report Form DRF-16: Measurement of Buffer Envelope Density using a Mercury Porosimeter

Procedure:	AGR-CHAR-DAM-16 Rev. 2
Operator:	S. D.NUNN
Buffer-coated kernel batch ID:	NUCO350-36B
Batch Description:	Buffer Coated BWXT Kernel Composite 69300
Thermocouple Expiration Date:	5/23/06
Penetrometer Expiration Date:	5/25/06
Completed DRF Filename:	\\mc-agr\AGR\Porosimeter\S05062006\S05062006R1_DRF16R2.xls

Mean average weight/buffer-coated kernel (g):	3.11E-04
Uncertainty in mean average weight/b-c kernel (g):	1.20E-06
Mean average weight/bare kernel (g):	2.31E-04
Uncertainty in mean average weight/bare kernel (g):	8.69E-07
Mean average envelope volume/bare kernel (cc):	2.14E-05
Uncertainty in envelope volume/bare kernel (cc):	5.47E-09

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Porosimeter data file number:	S05062006L	S05062007L	S05062008L	S05062101L	S05062102L
Weight of buffer-coated kernels (g):	4.0723	4.0655	4.0860	4.0696	4.0514
Approximate number of b-c kernels:	13094	13072	13138	13086	13027
Uncertainty in number of b-c kernels:	51	50	51	50	50
Total envelope volume of sample (cc):	1.226	1.227	1.232	1.226	1.217
Av. envelope volume/b-c kernels (cc):	9.37E-05	9.38E-05	9.38E-05	9.37E-05	9.34E-05
Sample envelope density (g/cc):	3.321	3.315	3.317	3.319	3.328

Mean average envelope volume/b-c kernel (cc):	9.37E-05
Uncertainty in envelope volume/b-c kernel (cc):	6.7E-08

Buffer density:	1.11E+00
Uncertainty in buffer density:	2.05E-02

S. D. Nunn
Operator

2/14/06
Date

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	Dixie Barker
Particle Lot ID:	NUCO350-36B
Particle Lot Description:	Buffer Coated NUCO
Filename:	\\mc-agr\AGR\ParticleWeight\W05062002_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	3.45E-02	3.26E-02	3.54E-02	3.58E-02	3.42E-02
Number of particles:	110	104	115	116	110
Average weight/particle (g):	3.14E-04	3.13E-04	3.08E-04	3.09E-04	3.11E-04

Mean average weight/particle (g):	3.11E-04
Uncertainty in mean average weight/particle (g):	1.20E-06

Dixie Barker
Operator

6-20-05
Date

Data Report Form DRF-16: Measurement of Buffer Envelope Density using a Mercury Porosimeter

Procedure:	AGR-CHAR-DAM-16 Rev. 2
Operator:	S. D.NUNN
Buffer-coated kernel batch ID:	NUCO350-54B
Batch Description:	Buffer Coated BWXT Kernel Composite 69300
Thermocouple Expiration Date:	5/23/06
Penetrometer Expiration Date:	5/25/06
Completed DRF Filename:	\\mc-agr\AGR\Porosimeter\S05062201\S05062201R1_DRF16R2.xls

Mean average weight/buffer-coated kernel (g):	3.11E-04
Uncertainty in mean average weight/b-c kernel (g):	1.09E-06
Mean average weight/bare kernel (g):	2.31E-04
Uncertainty in mean average weight/bare kernel (g):	8.69E-07
Mean average envelope volume/bare kernel (cc):	2.14E-05
Uncertainty in envelope volume/bare kernel (cc):	5.47E-09

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Porosimeter data file number:	S05062201L	S05062202L	S05062203L	S05062204L	S05062205L
Weight of buffer-coated kernels (g):	4.1223	4.0694	4.0160	4.0391	4.0471
Approximate number of b-c kernels:	13255	13085	12913	12987	13013
Uncertainty in number of b-c kernels:	46	46	45	46	46
Total envelope volume of sample (cc):	1.233	1.225	1.209	1.215	1.215
Av. envelope volume/b-c kernels (cc):	9.30E-05	9.36E-05	9.36E-05	9.35E-05	9.34E-05
Sample envelope density (g/cc):	3.344	3.323	3.323	3.326	3.331

Mean average envelope volume/b-c kernel (cc):	9.34E-05
Uncertainty in envelope volume/b-c kernel (cc):	1.1E-07

Buffer density:	1.11E+00
Uncertainty in buffer density:	1.94E-02

S. D. Nunn
Operator

2/14/06
Date

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	Dixie Barker
Particle Lot ID:	NUCO350-54B
Particle Lot Description:	Buffer Coated NUCO
Filename:	\\mc-agr\AGR\ParticleWeight\W05062101_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	3.66E-02	4.39E-02	3.80E-02	4.22E-02	3.97E-02
Number of particles:	118	140	123	135	129
Average weight/particle (g):	3.10E-04	3.14E-04	3.09E-04	3.13E-04	3.08E-04

Mean average weight/particle (g):	3.11E-04
Uncertainty in mean average weight/particle (g):	1.09E-06

Dixie Barker
Operator

6-21-05
Date

For Information Only

The information in the remainder of this section reports results of measurements not required by the fuel specification and is provided for information only.

Data Report Form DRF-16: Measurement of Buffer Envelope Density using a Mercury Porosimeter

Procedure:	AGR-CHAR-DAM-16 Rev. 2
Operator:	S. D.NUNN
Buffer-coated kernel batch ID:	NUCO350-58B
Batch Description:	Composite of Buffer Coated BWXT Kernel Composite 69300
Thermocouple Expiration Date:	5/23/06
Penetrometer Expiration Date:	5/25/06
Completed DRF Filename:	\\mc-agr\AGR\Porosimeter\S05062206\S05062206R1_DRF16R2.xls

Mean average weight/buffer-coated kernel (g):	3.09E-04
Uncertainty in mean average weight/b-c kernel (g):	4.99E-07
Mean average weight/bare kernel (g):	2.31E-04
Uncertainty in mean average weight/bare kernel (g):	8.69E-07
Mean average envelope volume/bare kernel (cc):	2.14E-05
Uncertainty in envelope volume/bare kernel (cc):	5.47E-09

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Porosimeter data file number:	S05062206L	S05062207L	S05062301L	S05062302L	S05062303L
Weight of buffer-coated kernels (g):	4.3399	4.3264	4.3459	4.4478	4.3485
Approximate number of b-c kernels:	14045	14001	14064	14394	14073
Uncertainty in number of b-c kernels:	23	23	23	23	23
Total envelope volume of sample (cc):	1.300	1.296	1.300	1.333	1.303
Av. envelope volume/b-c kernels (cc):	9.25E-05	9.26E-05	9.24E-05	9.26E-05	9.26E-05
Sample envelope density (g/cc):	3.340	3.338	3.344	3.337	3.338

Mean average envelope volume/b-c kernel (cc):	9.25E-05
Uncertainty in envelope volume/b-c kernel (cc):	3.8E-08

Buffer density:	1.10E+00
Uncertainty in buffer density:	1.41E-02

S. D. Nunn
Operator

2/14/06
Date

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	Dixie Barker
Particle Lot ID:	NUCO350-58B
Particle Lot Description:	Composite of Buffer Coated BWXT Kernel Composite 69300
Filename:	\\mc-agr\AGR\ParticleWeight\W05062201_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	3.35E-02	3.07E-02	4.09E-02	3.50E-02	4.08E-02
Number of particles:	109	99	132	113	132
Average weight/particle (g):	3.07E-04	3.10E-04	3.10E-04	3.10E-04	3.09E-04

Mean average weight/particle (g):	3.09E-04
Uncertainty in mean average weight/particle (g):	4.99E-07

Dixie Barker
Operator

6-22-05
Date

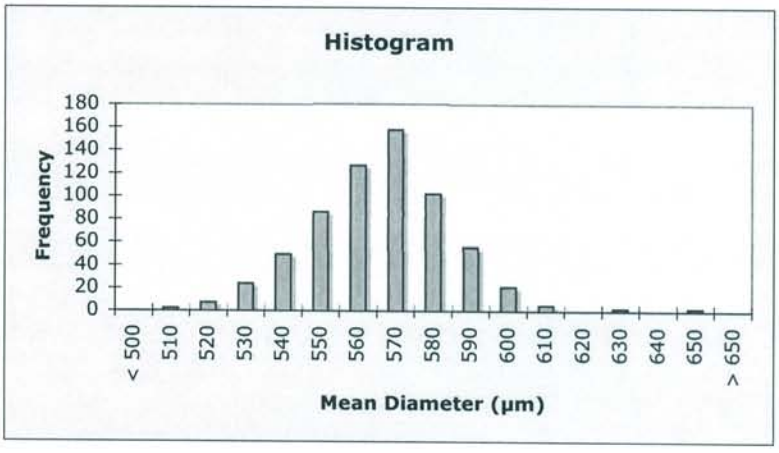
Data Report Form DRF-10A: Measurement of Particle Diameter

Procedure:	AGR-CHAR-DAM-10 Rev. 0
Operator:	Andy Nelson
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P05062401
Sample ID:	NUCO350-58B
Sample Description:	Composite of Buffer-coated BWXT Kernel Composite 69300
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P05062401_output

Number of particles analyzed:	640
Mean of the average diameter of each particle (μm):	561
Standard deviation in the average diameter of each particle (μm):	18

Distribution of the average particle diameter (top binned)

Mean Diameter	*Frequency*
< 500	0
510	2
520	7
530	24
540	49
550	86
560	127
570	158
580	102
590	55
600	21
610	5
620	0
630	2
640	0
650	2
> 650	0



Operator

6/27/2005

Date

Data Report Form DRF-16: Measurement of Buffer Envelope Density using a Mercury Porosimeter

Procedure:	AGR-CHAR-DAM-16 Rev. 2
Operator:	S. D. NUNN
Buffer-coated kernel batch ID:	LEU01-16B
Batch Description:	Buffer on BWXT LEUCO kernel composite 69302
Thermocouple Expiration Date:	5/23/06
Penetrometer Expiration Date:	5/25/06
Completed DRF Filename:	\\mc-agr\AGR\Porosimeter\S05110701\S05110701R1_DRF16R2.xls

Mean average weight/buffer-coated kernel (g):	3.20E-04
Uncertainty in mean average weight/b-c kernel (g):	8.22E-07
Mean average weight/bare kernel (g):	2.42E-04
Uncertainty in mean average weight/bare kernel (g):	5.96E-07
Mean average envelope volume/bare kernel (cc):	2.21E-05
Uncertainty in envelope volume/bare kernel (cc):	1.34E-08

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Porosimeter data file number:	S05110701L	S05110702L	S05110703L	S05110704L	S05110705L
Weight of buffer-coated kernels (g):	4.0951	4.1007	4.2203	4.2527	4.3448
Approximate number of b-c kernels:	12797	12815	13188	13290	13578
Uncertainty in number of b-c kernels:	33	33	34	34	35
Total envelope volume of sample (cc):	1.192	1.193	1.234	1.229	1.267
Av. envelope volume/b-c kernels (cc):	9.32E-05	9.31E-05	9.36E-05	9.25E-05	9.33E-05
Sample envelope density (g/cc):	3.435	3.438	3.421	3.460	3.430

Mean average envelope volume/b-c kernel (cc):	9.31E-05
Uncertainty in envelope volume/b-c kernel (cc):	1.8E-07

Buffer density:	1.10E+00
Uncertainty in buffer density:	1.46E-02

S. D. Nunn
Operator

2/14/06
Date

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	Dixie Barker
Particle Lot ID:	LEU01-16B
Particle Lot Description:	Buffer on BWXT kernel composite 69302
Filename:	\\mc-agr\AGR\ParticleWeight\W05110701_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	6.21E-02	6.72E-02	5.58E-02	5.12E-02	6.32E-02
Number of particles:	194	209	175	159	199
Average weight/particle (g):	3.20E-04	3.22E-04	3.19E-04	3.22E-04	3.18E-04

Mean average weight/particle (g):	3.20E-04
Uncertainty in mean average weight/particle (g):	8.22E-07

Dixie Barker
Operator

11-7-05
Date

Data Report Form DRF-16: Measurement of Buffer Envelope Density using a Mercury Porosimeter

Procedure:	AGR-CHAR-DAM-16 Rev. 3
Operator:	S. D. Nunn
Buffer-coated kernel batch ID:	DUN350-19B
Batch Description:	Buffer coated DUN350 kernels
Thermocouple Expiration Date:	5/19/07
Penetrometer Expiration Date:	5/25/07
Completed DRF Filename:	\\mc-agr\AGR\Porosimeter\S06082304\S06082304_DRF16R3.xls

Mean average weight/buffer-coated kernel (g):	3.31E-04
Standard error in mean average weight/b-c kernel (g):	1.16E-06
Mean average weight/bare kernel (g):	2.51E-04
Standard error in mean average weight/bare kernel (g):	1.33E-06
Mean average envelope volume/bare kernel (cc):	2.31E-05
Standard error in mean envelope volume/bare kernel (cc):	3.00E-08

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Porosimeter data file number:	S06082304	S06082305	S06082306		
Weight of buffer-coated kernels (g):	4.0932	4.1073	4.3608		
Approximate number of b-c kernels:	12366	12409	13175		
Uncertainty in number of b-c kernels:	43	43	46		
Total envelope volume of sample (cc):	1.175	1.181	1.253		
Av. envelope volume/b-c kernels (cc):	9.50E-05	9.52E-05	9.51E-05		
Sample envelope density (g/cc):	3.484	3.478	3.480		

Mean average envelope volume/b-c kernel (cc):	9.51E-05
Standard error in mean envelope volume/b-c kernel (cc):	4.6E-08

Mean buffer density:	1.11E+00
Standard deviation in buffer density:	5.48E-02

S. D. Nunn
Operator

8/23/06
Date

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	Dixie Barker
Particle Lot ID:	DUN350-19B
Particle Lot Description:	Buffer coated DUN350 kernels
Filename:	\\mc-agr\AGR\ParticleWeight\W06082301_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	6.12E-02	6.49E-02	6.83E-02	5.50E-02	5.62E-02
Number of particles:	184	198	204	166	170
Average weight/particle (g):	3.33E-04	3.28E-04	3.35E-04	3.31E-04	3.31E-04

Mean average weight/particle (g):	3.31E-04
Standard error in mean average weight/particle (g):	1.16E-06

Dixie Barker
Operator

8-23-06
Date

11 Characterization of IPyC on interrupted batches

This section contains data on the inner pyrocarbon (IPyC) coating density and other properties for particles removed from the coater after deposition of only the buffer and IPyC layers. The IPyC density data from these interrupted coating runs was originally used to qualify the AGR-1 baseline coating process for the IPyC density. The data was obtained according to product inspection plan AGR-CHAR-PIP-02R4. IPyC density values had to be obtained from these interrupted batches because it is not feasible to measure the IPyC density after all coating layers are applied. According to section 5.3 of the AGR-1 Fuel Product Specification and Characterization Guidance (EDF-4380, Rev. 6), three representative IPyC layers from interrupted batches which met the specification for IPyC density were sufficient to qualify the process for IPyC density. The qualifying batches used nominally 350 μm diameter natural uranium oxide/uranium carbide kernels (NUCO). The kernels were obtained from BWXT and were identified as composite G73B-NU-69300. The use of the NUCO surrogate kernels was not expected to significantly affect the density of the IPyC. To check this assumption for the AGR-1 acceptance tests, a confirmatory batch using LEUCO kernels from composite G73D-20-69302 (LEU01) was coated and the measured density was found to be within the range predicted by the NUCO qualification batches.

According to section 5.3 of EDF-6638, Rev. 1, this data also constitutes IPyC density acceptance for the AGR-3/4 driver fuel coating process, provided that the relative coating conditions are essentially the same. Table 11-1 compares the relevant coating conditions specified in section 5.3 of EDF-6638, Rev. 1. The average surface area of the kernel charge was calculated from the weight of the kernel charge for each batch, the average kernel weight, and the average kernel diameter (assuming a spherical kernel). The range for the batches in each series is given and all the values are equivalent, within the combined uncertainties of the particle weight, diameter, and shape. The other coating conditions were taken directly from the run sheets in section 3 and are identical, with the exception of a negligible difference in the TGF.

Table 11-1. Comparison of buffer/IPyC coating conditions

	NUCO qualification batches	AGR-1 baseline batches	AGR-3/4 driver batches
Average surface area of kernel charge	1001.8-1012.3 cm^2	1003.8-1008.3 cm^2	1008.0-1009.1 cm^2
Buffer deposition temperature	1450°C	1450°C	1450°C
Buffer total gas flowrate (TGF)	8530 sccm	8530 sccm	8540 sccm
Buffer coating gas fraction (CGF)	$0.61\ \frac{C_2H_2}{TGF}$	$0.61\ \frac{C_2H_2}{TGF}$	$0.61\ \frac{C_2H_2}{TGF}$
IPyC deposition temperature	1265°C	1265°C	1265°C
IPyC total gas flowrate (TGF)	9430 sccm	9435 sccm	9430 sccm
IPyC coating gas fraction (CGF)	$0.30\ \frac{C_2H_2 + C_3H_6}{TGF}$	$0.30\ \frac{C_2H_2 + C_3H_6}{TGF}$	$0.30\ \frac{C_2H_2 + C_3H_6}{TGF}$
IPyC coating gas ratio (CGR)	$0.85\ \frac{C_2H_2}{C_3H_6}$	$0.85\ \frac{C_2H_2}{C_3H_6}$	$0.85\ \frac{C_2H_2}{C_3H_6}$

The following page shows the inspection report form (IRF-02B). Following IRF-02B are the individual data report forms for the measurements that were performed. Additional data at the end of this section is provided for information only. The process conditions used to deposit the IPyC layer for the batches in the LEU03-09T composite were determined to produce an IPyC density which satisfies the specifications in section 5.3 of EDF 6638, Rev. 1.

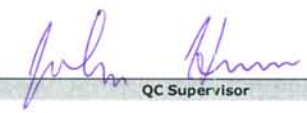
Inspection Report Form IRF-02B: Interrupted Coating Batches - IPyC Density

Procedure:	AGR-CHAR-PIP-02 Rev. 4
Batch 1 ID:	NUCO350-30BI
Batch 1 description:	IPyC/Buffer on BWXT kernel composite 69300
Batch 2 ID:	NUCO350-37BI
Batch 2 description:	IPyC/Buffer on BWXT kernel composite 69300
Batch 3 ID:	NUCO350-29BI
Batch 3 description:	IPyC/Buffer on BWXT kernel composite 69300

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	k or t value	INL EDF-4380 Rev. 6				
Batch 1: IPyC sink/float density (Mg/m³)	1.8917	0.0113	25	1.711	mean 1.90 ± 0.05	A = x - ts/√n ≥ 1.85	1.888	pass	DRF-03
						B = x + ts/√n ≤ 1.95	1.896	pass	
				3.158	dispersion ≤0.01 ≤ 1.80 ≤0.01 ≥ 2.00	C = x - ks > 1.80	1.856	pass	
						D = x + ks < 2.00	1.927	pass	
Batch 2: IPyC sink/float density (Mg/m³)	1.9038	0.0153	21	1.725	mean 1.90 ± 0.05	A = x - ts/√n ≥ 1.85	1.898	pass	DRF-03
						B = x + ts/√n ≤ 1.95	1.910	pass	
				3.262	dispersion ≤0.01 ≤ 1.80 ≤0.01 ≥ 2.00	C = x - ks > 1.80	1.854	pass	
						D = x + ks < 2.00	1.954	pass	
Batch 3: IPyC sink/float density (Mg/m³)	1.9112	0.0142	20	1.729	mean 1.90 ± 0.05	A = x - ts/√n ≥ 1.85	1.906	pass	DRF-03
						B = x + ts/√n ≤ 1.95	1.917	pass	
				3.295	dispersion ≤0.01 ≤ 1.80 ≤0.01 ≥ 2.00	C = x - ks > 1.80	1.864	pass	
						D = x + ks < 2.00	1.958	pass	

Comments

95% confidence interval for Buffer thickness in composite = (104μm, 106μm) with <1% ≤55μm.
95% confidence interval for IPyC thickness in composite = (34.2μm, 34.9μm) with >1% ≤30μm and <1% ≥56μm.
Confirmatory batch on LEUCO kernels, LEU01-15I: mean IPyC density = 1.9074 g/cc.



QC Supervisor

3-10-06

Date

Accept process for IPyC density (Yes or No):	Yes

QA Reviewer

3/29/06

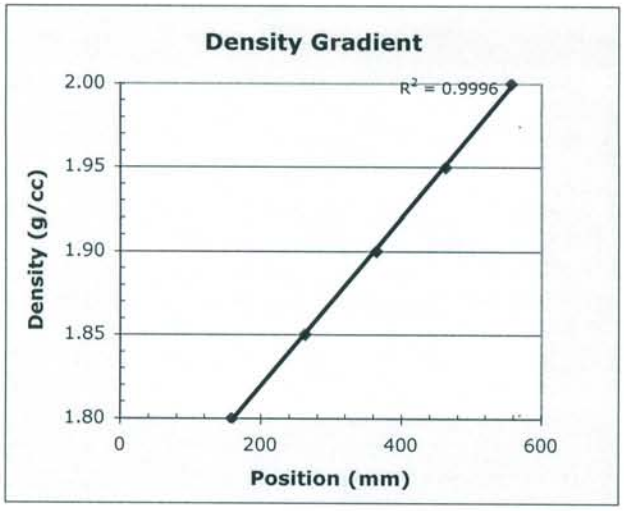
Date

Data Report Form DRF-03: Measurement of PyC Density using a Density Gradient Column

Procedure:	AGR-CHAR-DAM-03 Rev. 1
Operator:	Dixie Barker
Filename:	\\mc-agr\AGR\DensityColumn\D05062901_DRF03R1.xls
Sample ID:	NUCO350-30BI-B
Sample Description:	IPyC/Buffer on BWXT kernel composite 69300
Float Expiration Date:	07/2007
Gauge Expiration Date:	01/2006
Bath Temperature:	23.1C

Calibrated Floats			
Density	Top of Float	Bottom of Float	Center of Mass
1.800	154.64	163.83	159.24
1.850	258.61	266.87	262.74
1.900	361.46	367.13	364.30
1.950	459.26	467.16	463.21
2.000	553.39	560.32	556.86

Linear Fit			
slope	StDev	intercept	StDev
5.02E-04	3.18E-06	1.72E+00	1.25E-03



Sample Density			
Particle Number	Particle Position	Calculated Density	Standard Error
1	295.22	1.8668	0.0016
2	304.23	1.8714	0.0016
3	325.99	1.8823	0.0016
4	326.44	1.8825	0.0016
5	326.76	1.8827	0.0016
6	328.81	1.8837	0.0016
7	326.67	1.8826	0.0016
8	333.83	1.8862	0.0016
9	335.75	1.8872	0.0016
10	334.07	1.8863	0.0016
11	335.11	1.8869	0.0016
12	336.64	1.8876	0.0016
13	348.87	1.8938	0.0017
14	348.31	1.8935	0.0017
15	350.33	1.8945	0.0017
16	351.97	1.8953	0.0017
17	355.50	1.8971	0.0017
18	357.75	1.8982	0.0017
19	359.46	1.8991	0.0017
20	364.06	1.9014	0.0017
21	363.84	1.9013	0.0017
22	362.42	1.9006	0.0017
23	368.25	1.9035	0.0017
24	385.58	1.9122	0.0018
25	390.04	1.9144	0.0018
Average Density		1.8917	0.0003
Standard Deviation		0.0113	

Dixie Barker
Operator

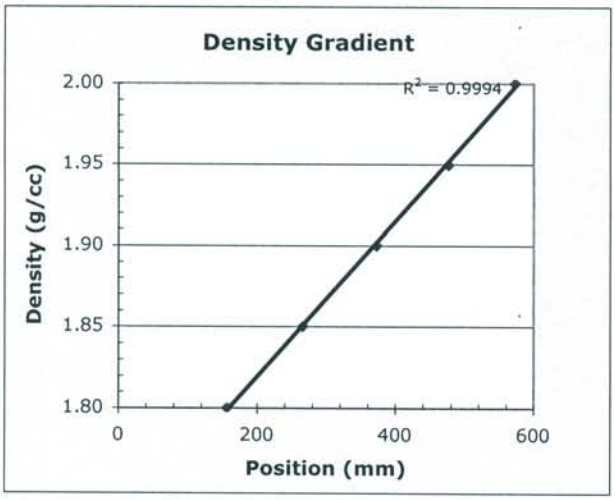
6-29-05
Date

Data Report Form DRF-03: Measurement of PyC Density using a Density Gradient Column

Procedure:	AGR-CHAR-DAM-03 Rev. 1
Operator:	Dixie Barker
Filename:	\\mc-agr\AGR\DensityColumn\D05063001_DRF03R1.xls
Sample ID:	NUCO350-37BI-B
Sample Description:	IPyC/Buffer on BWXT kernel composite 69300
Float Expiration Date:	07/2007
Gauge Expiration Date:	01/2006
Bath Temperature:	22.9C

Calibrated Floats			
Density	Top of Float	Bottom of Float	Center of Mass
1.800	151.98	161.42	156.70
1.850	262.34	270.69	266.52
1.900	370.32	376.20	373.26
1.950	473.40	480.73	477.07
2.000	569.44	576.52	572.98

Linear Fit			
slope	StDev	intercept	StDev
4.79E-04	2.94E-06	1.72E+00	1.17E-03



Sample Density			
Particle Number	Particle Position	Calculated Density	Standard Error
1	313.15	1.8731	0.0015
2	329.08	1.8807	0.0015
3	335.13	1.8836	0.0015
4	342.49	1.8872	0.0015
5	349.04	1.8903	0.0016
6	351.34	1.8914	0.0016
7	365.21	1.8980	0.0016
8	367.09	1.8989	0.0016
9	367.27	1.8990	0.0016
10	378.19	1.9043	0.0016
11	382.30	1.9062	0.0016
12	386.45	1.9082	0.0016
13	387.67	1.9088	0.0016
14	389.34	1.9096	0.0016
15	390.40	1.9101	0.0016
16	404.73	1.9170	0.0017
17	409.36	1.9192	0.0017
18	412.62	1.9207	0.0017
19	412.95	1.9209	0.0017
20	418.50	1.9236	0.0017
21	428.34	1.9283	0.0017
22			
23			
24			
25			
Average Density		1.9038	0.0004
Standard Deviation		0.0153	

Dixie Barker
Operator

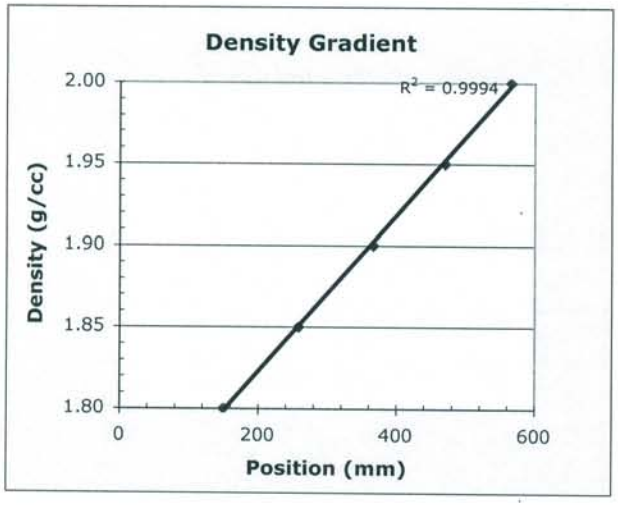
6-30-05
Date

Data Report Form DRF-03: Measurement of PyC Density using a Density Gradient Column

Procedure:	AGR-CHAR-DAM-03 Rev. 1
Operator:	Dixie Barker
Filename:	\\mc-agr\AGR\DensityColumn\D05070101_DRF03R1.xls
Sample ID:	NUCO350-29BI-B
Sample Description:	Ipyc/Buffer on BWXT kernel composite 69300
Float Expiration Date:	07/2007
Gauge Expiration Date:	01/2006
Bath Temperature:	23.3C

Calibrated Floats			
Density	Top of Float	Bottom of Float	Center of Mass
1.800	145.75	154.69	150.22
1.850	254.86	262.94	258.90
1.900	363.03	368.69	365.86
1.950	466.04	473.41	469.73
2.000	561.98	569.07	565.53

Linear Fit			
slope	StDev	intercept	StDev
4.80E-04	3.17E-06	1.73E+00	1.15E-03



Sample Density			
Particle Number	Particle Position	Calculated Density	Standard Error
1	321.45	1.8805	0.0015
2	336.71	1.8878	0.0016
3	341.90	1.8903	0.0016
4	358.02	1.8981	0.0016
5	368.37	1.9030	0.0016
6	374.74	1.9061	0.0017
7	373.30	1.9054	0.0017
8	379.31	1.9083	0.0017
9	382.20	1.9097	0.0017
10	383.00	1.9101	0.0017
11	390.54	1.9137	0.0017
12	390.54	1.9137	0.0017
13	405.88	1.9210	0.0017
14	406.48	1.9213	0.0017
15	408.91	1.9225	0.0017
16	409.63	1.9228	0.0017
17	414.97	1.9254	0.0017
18	423.66	1.9296	0.0018
19	429.22	1.9322	0.0018
20	410.67	1.9233	0.0017
21			
22			
23			
24			
25			
Average Density		1.9112	0.0004
Standard Deviation		0.0142	

Dixie Barker
Operator

7-1-05
Date

For Information Only

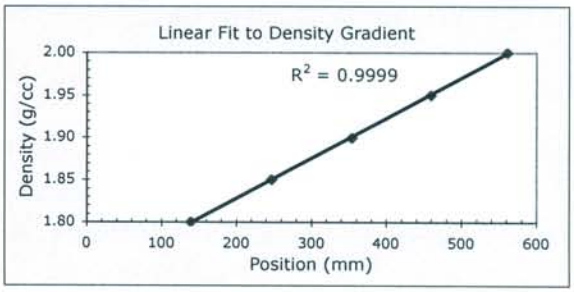
The information in the remainder of this section reports results of measurements not required by the fuel specification and is provided for information only.

Data Report Form DRF-03: Measurement of PyC Density using a Density Gradient Column

Procedure:	AGR-CHAR-DAM-03 Rev. 2
Operator:	Dixie Barker
Filename:	\\mc-agr\AGR\DensityColumn\D05110801_DRF03R2.xls
Sample ID:	LEU01-15I-B01
Sample description:	IPyC/Buffer on BWXT kernel composite 69302
Float expiration date:	07/2007
Gauge expiration date:	01/2006
Bath temperature:	22.7 °C

Calibrated Floats			
Density	Top of Float	Bottom of Float	Center of Mass
1.800	134.80	144.21	139.51
1.850	243.34	251.54	247.44
1.900	351.28	357.11	354.20
1.950	456.05	463.23	459.64
2.000	557.73	565.05	561.39

Linear Fit			
slope	StDev	intercept	StDev
4.73E-04	2.74E-06	1.73E+00	9.73E-04



Sample Density								
Fragment Number	Fragment Position	Calculated Density	Fragment Number	Fragment Position	Calculated Density	Fragment Number	Fragment Position	Calculated Density
1	304.62	1.8774	26	370.16	1.9084	51		
2	311.60	1.8807	27	370.85	1.9087	52		
3	316.86	1.8832	28	369.53	1.9081	53		
4	324.68	1.8869	29	374.00	1.9102	54		
5	328.13	1.8885	30	375.99	1.9112	55		
6	332.97	1.8908	31	381.77	1.9139	56		
7	334.87	1.8917	32	382.71	1.9143	57		
8	338.02	1.8932	33	384.42	1.9151	58		
9	338.84	1.8936	34	385.50	1.9157	59		
10	340.51	1.8944	35	386.44	1.9161	60		
11	341.77	1.8950	36	386.80	1.9163	61		
12	341.09	1.8946	37	387.69	1.9167	62		
13	341.09	1.8946	38	388.54	1.9171	63		
14	351.54	1.8996	39	391.14	1.9183	64		
15	352.97	1.9003	40	392.11	1.9188	65		
16	354.39	1.9009	41	393.13	1.9193	66		
17	358.58	1.9029	42	396.08	1.9207	67		
18	359.74	1.9035	43	397.78	1.9215	68		
19	358.62	1.9029	44	399.01	1.9221	69		
20	360.57	1.9039	45	400.37	1.9227	70		
21	361.40	1.9042	46	403.99	1.9244	71		
22	362.69	1.9049	47	407.97	1.9263	72		
23	365.05	1.9060	48	408.28	1.9264	73		
24	367.05	1.9069	49	420.44	1.9322	74		
25	369.10	1.9079	50	428.33	1.9359	75		

Average density of PyC fragments:	1.9074
Standard deviation in density of PyC fragments:	0.0136
Uncertainty in calculated density of PyC fragments:	0.0015

Dixie Barker
Operator

11-8-05
Date

Summary of "info only" measurements

Coating Thickness

		Buffer thickness (µm)	IPyC thickness (µm)
Batch 1	NUCO350-30BI-C	99	36.3
Batch 2	NUCO350-37BI-C	102	35.1
Batch 3	NUCO350-29BI-C	107	33.9
Average		103	35.1
Composite	NUCO350-66BI-C	105	34.5

Open Porosity

		Average particle weight (g)	Open porosity (ml/m^2)
Composite	NUCO350-66BI	3.95E-04	1.65
Confirmatory	LEU01-15I	4.26E-04	1.56

Note: The open porosity measurement on the IPyC was calculated from the mercury intrusion between 250 psi and 10000 psi per table 5.3 in EDF-4380, Rev. 6. In the upper half of this pressure range, there is some compression of the buffer layer that results in a value for open porosity that is higher than the actual value. The open porosity of the IPyC in LEU01-15I, calculated from the mercury intrusion between 250 psi and 5000 psi, was 1.20 ml/m^2 which corresponds well with the open porosity measured for OPyC deposited under similar conditions. The open porosity of the IPyC in NUCO350-66BI, calculated from the mercury intrusion between 250 psi and 5000 psi, was 1.19 ml/m^2. Porosimetry measurements on OPyC, where compression between 5000 psi and 10000 psi is negligible, show little mercury intrusion above 5000 psi.

Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 0
Operator:	Andrew K. Kercher
Sample ID:	NUCO350-30BI-C
Sample Description:	IPyC/Buffer on BWXT kernel composite 69300 -- repolished
Mount Number(s):	M05062902
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P05070101

DMR Calibration Expiration Date:	3/24/06
Stage Micrometer Calibration Expiration Date:	2/17/07
Measured Value for 500 µm in Stage Micrometer Image:	500.4 µm

Andrew K. Kercher 9/9/

Operator

07/01/05

Date

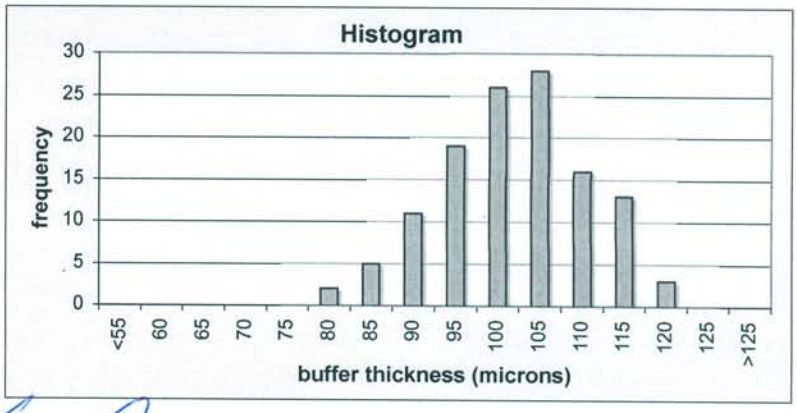
Data Report Form DRF-11A: Measurement of Buffer Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 1
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P05070101\
Sample ID:	NUCO350-30BI-C (repolished sample)
Sample Description:	IPyC/Buffer on BWXT kernel composite 69300
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P05070101_output\

Number of buffer layers analyzed:	123
Mean of the average buffer thickness of each particle (μm):	99.4
Standard deviation in the average buffer thickness of each particle (μm):	8.8

Distribution of the average buffer layer thickness (top binned)

Buffer Thickness (μm)	*Frequency*
<55	0
60	0
65	0
70	0
75	0
80	2
85	5
90	11
95	19
100	26
105	28
110	16
115	13
120	3
125	0
>125	0



Operator

July 19, 2005
Date

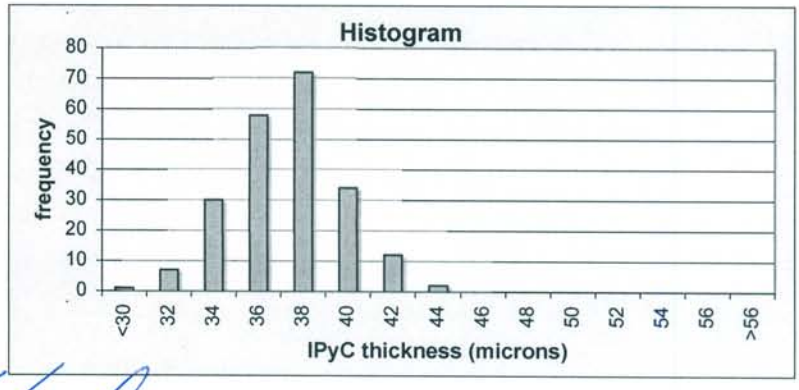
Data Report Form DRF-11B: Measurement of Inner Pyrocarbon Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 1
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P05070101\
Sample ID:	NUCO350-30BI-C (repolished sample)
Sample Description:	IPyC/Buffer on BWXT kernel composite 69300
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P05070101_output\

Number of inner pyrocarbon layers analyzed:	216
Mean of the average IPyC thickness of each particle (μm):	36.3
Standard deviation in the average IPyC thickness of each particle (μm):	2.4

Distribution of the average IPyC layer thickness (top binned)

IPyC Thickness (μm)	*Frequency*
<30	1
32	7
34	30
36	58
38	72
40	34
42	12
44	2
46	0
48	0
50	0
52	0
54	0
56	0
>56	0



Andrew K. Kercher
Operator

July 19, 2005
Date

Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 0
Operator:	Andrew K. Kercher
Sample ID:	NUCO350-37BI-C
Sample Description:	IPyC/Buffer on BWXT kernel composite 69300
Mount Number(s):	M05063001
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P05070501\

DMR Calibration Expiration Date:	3/24/06
Stage Micrometer Calibration Expiration Date:	2/17/07
Measured Value for 500 µm in Stage Micrometer Image:	500.7 µm

Andrew K. Kercher — Operator

07/05/05 — Date

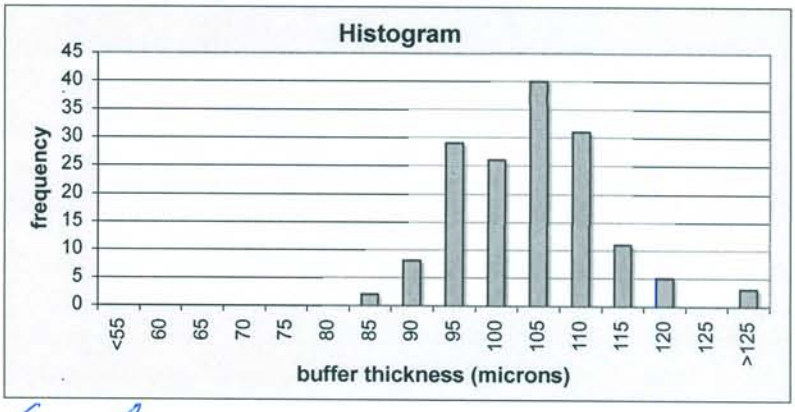
Data Report Form DRF-11A: Measurement of Buffer Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 1
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P05070501\
Sample ID:	NUCO350-37BI-C
Sample Description:	IPyC/Buffer on BWXT kernel composite 69300
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P05070501_output\

Number of buffer layers analyzed:	155
Mean of the average buffer thickness of each particle (μm):	101.5
Standard deviation in the average buffer thickness of each particle (μm):	8.9

Distribution of the average buffer layer thickness (top binned)

Buffer Thickness (μm)	*Frequency*
<55	0
60	0
65	0
70	0
75	0
80	0
85	2
90	8
95	29
100	26
105	40
110	31
115	11
120	5
125	0
>125	3



Andrew K. Kercher — Operator

July 19, 2005 — Date

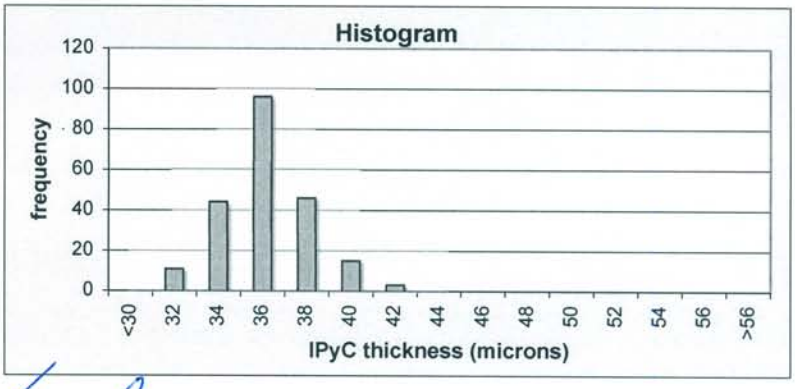
Data Report Form DRF-11B: Measurement of Inner Pyrocarbon Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 1
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P05070501\
Sample ID:	NUCO350-37BI-C
Sample Description:	IPyC/Buffer on BWXT kernel composite 69300
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P05070501_output\

Number of inner pyrocarbon layers analyzed:	215
Mean of the average IPyC thickness of each particle (μm):	35.1
Standard deviation in the average IPyC thickness of each particle (μm):	2.0

Distribution of the average IPyC layer thickness (top binned)

IPyC Thickness (μm)	*Frequency*
<30	0
32	11
34	44
36	96
38	46
40	15
42	3
44	0
46	0
48	0
50	0
52	0
54	0
56	0
>56	0



Andrew K. Kercher — Operator

July 19, 2005 — Date

Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 0
Operator:	Andrew K. Kercher
Sample ID:	NUCO350-29BI-C
Sample Description:	IPyC/Buffer on BWXT kernel composite 69300
Mount Number(s):	M05070101
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P05070601\

DMR Calibration Expiration Date:	3/24/06
Stage Micrometer Calibration Expiration Date:	2/17/07
Measured Value for 500 µm in Stage Micrometer Image:	499.6 µm

Operator

07/06/05

Date

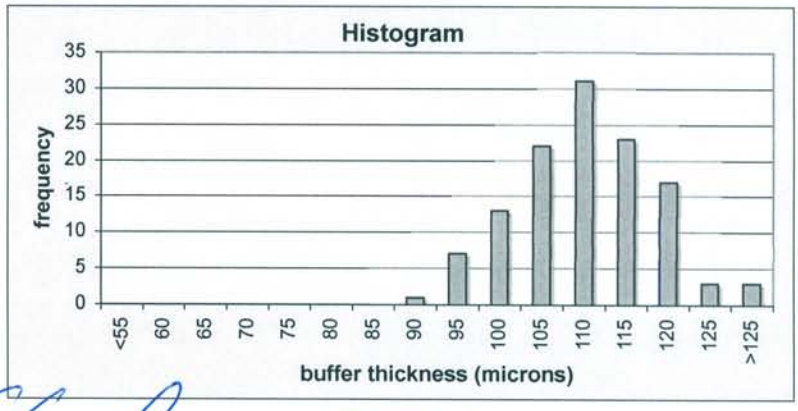
Data Report Form DRF-11A: Measurement of Buffer Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 1
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P05070601\
Sample ID:	NUCO350-29BI-C
Sample Description:	IPyC/Buffer on BWXT kernel composite 69300
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P05070601_output\

Number of buffer layers analyzed:	120
Mean of the average buffer thickness of each particle (μm):	107.3
Standard deviation in the average buffer thickness of each particle (μm):	8.0

Distribution of the average buffer layer thickness (top binned)

Buffer Thickness (μm)	*Frequency*
<55	0
60	0
65	0
70	0
75	0
80	0
85	0
90	1
95	7
100	13
105	22
110	31
115	23
120	17
125	3
>125	3



Operator

July 19, 2005

Date

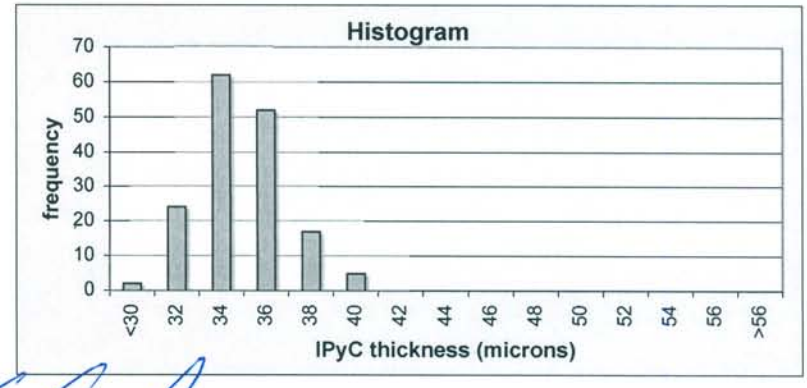
Data Report Form DRF-11B; Measurement of Inner Pyrocarbon Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 1
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P05070601\
Sample ID:	NUCO350-29BI-C
Sample Description:	IPyC/Buffer on BWXT kernel composite 69300
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P05070601_output\

Number of inner pyrocarbon layers analyzed:	162
Mean of the average IPyC thickness of each particle (μm):	33.9
Standard deviation in the average IPyC thickness of each particle (μm):	2.0

Distribution of the average IPyC layer thickness (top binned)

IPyC Thickness (μm)	*Frequency*
<30	2
32	24
34	62
36	52
38	17
40	5
42	0
44	0
46	0
48	0
50	0
52	0
54	0
56	0
>56	0



Andrew K. Kercher — Operator

July 19, 2005 — Date

Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 0
Operator:	Andrew K. Kercher
Sample ID:	NUCO350-66BI-C
Sample Description:	Composite (30BI+37BI+29BI) IPyC/Buffer on BWXT composite 69300
Mount Number(s):	M05070601
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P05070602\

DMR Calibration Expiration Date:	3/24/06
Stage Micrometer Calibration Expiration Date:	2/17/07
Measured Value for 500 µm in Stage Micrometer Image:	499.6 µm

Andrew K. Kercher — Operator

07/06/05 — Date

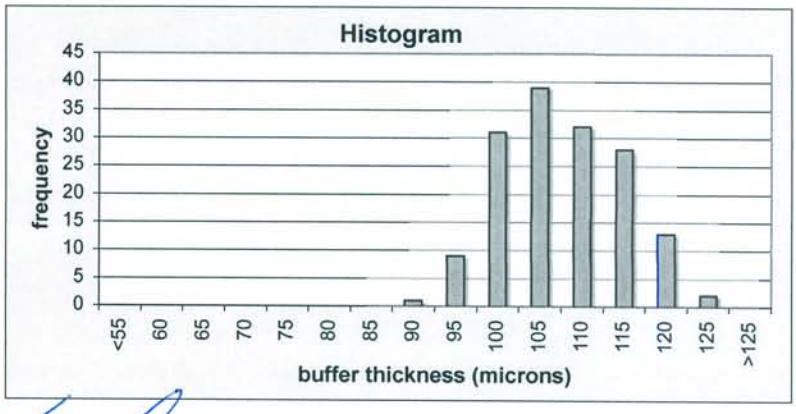
Data Report Form DRF-11A: Measurement of Buffer Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 1
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P05070602\
Sample ID:	NUCO350-66BI-C
Sample Description:	Composite (30BI+37BI+29BI) IPyC/Buffer on BWXT composite 69300
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P05070602_output\

Number of buffer layers analyzed:	155
Mean of the average buffer thickness of each particle (μm):	105.3
Standard deviation in the average buffer thickness of each particle (μm):	7.2

Distribution of the average buffer layer thickness (top binned)

Buffer Thickness (μm)	*Frequency*
<55	0
60	0
65	0
70	0
75	0
80	0
85	0
90	1
95	9
100	31
105	39
110	32
115	28
120	13
125	2
>125	0



Andrew K. Kercher — Operator

July 19, 2005 — Date

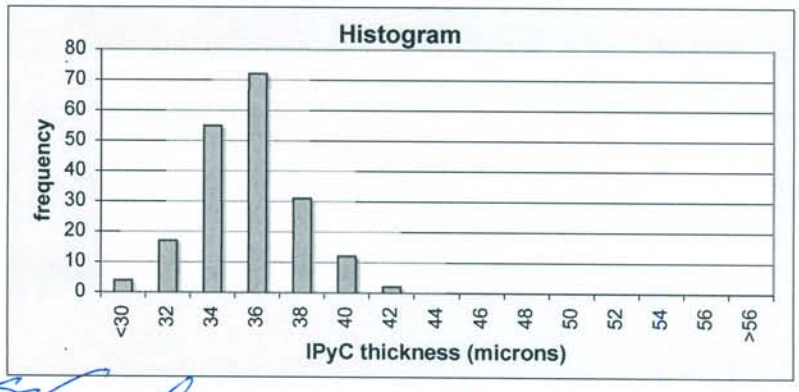
Data Report Form DRF-11B: Measurement of Inner Pyrocarbon Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 1
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P05070602\
Sample ID:	NUCO350-66BI-C
Sample Description:	Composite (30BI+37BI+29BI) IPyC/Buffer on BWXT composite 69300
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P05070602_output\

Number of inner pyrocarbon layers analyzed:	193
Mean of the average IPyC thickness of each particle (μm):	34.5
Standard deviation in the average IPyC thickness of each particle (μm):	2.2

Distribution of the average IPyC layer thickness (top binned)

IPyC Thickness (μm)	*Frequency*
<30	4
32	17
34	55
36	72
38	31
40	12
42	2
44	0
46	0
48	0
50	0
52	0
54	0
56	0
>56	0



Operator

July 19, 2005
Date

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	Dixie Barker
Particle Lot ID:	NUCO350-66BI
Particle Lot Description:	Composite (30BI+37BI+29BI) IPyC/Buffer on BWXT 69300
Filename:	\\mc-agr\AGR\ParticleWeight\W05072101__DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	7.92E-02	9.73E-02	8.60E-02	8.78E-02	7.42E-02
Number of particles:	201	246	218	222	188
Average weight/particle (g):	3.94E-04	3.96E-04	3.94E-04	3.95E-04	3.95E-04

Mean average weight/particle (g):	3.95E-04
Uncertainty in mean average weight/particle (g):	2.92E-07

Dixie Barker
Operator

7-21-05
Date

Data Report Form DRF-31: Measurement of Open Porosity using a Mercury Porosimeter

Procedure:	AGR-CHAR-DAM-31 Rev. 0
Operator:	S. D. Nunn
Coated particle batch ID:	NUCO350-66BI-E
Batch Description:	IPyC coated BWXT NUCO composite 69300
Thermocouple Expiration Date:	5/23/06
Penetrometer Expiration Date:	5/25/06
Completed DRF Filename:	\\mc-agr\AGR\Porosimeter\S05071402\S05071402_DRF31R0.xls

Mean average weight/particle (g):	3.95E-04
Uncertainty in mean average weight/particle (g):	2.92E-07

Weight of particles (g):	4.1698
Approximate number of particles:	10556
Uncertainty in number of particles:	8
Total envelope volume of sample (cc):	1.391
Average envelope volume/particle (cc):	1.32E-04
Sample envelope density (g/cc):	2.998

Average particle diameter (microns):	6.31E+02
Average surface area/particle (cm2):	1.25E-02
Total sample surface area (cm2):	1.32E+02
Intruded mercury volume from 250-10,000 psia (cc):	2.18E-02
Open porosity (ml/m2):	1.65E+00

S. D. Nunn
Operator

10/7/05
Date

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	Dixie Barker
Particle Lot ID:	LEUC0-15I-CO1
Particle Lot Description:	Buffer on BWXT kernel composite 69302
Filename:	\\mc-agr\AGR\ParticleWeight\W05110702_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	6.97E-02	6.15E-02	5.69E-02	5.93E-02	6.72E-02
Number of particles:	163	144	134	139	159
Average weight/particle (g):	4.28E-04	4.27E-04	4.25E-04	4.27E-04	4.23E-04

Mean average weight/particle (g):	4.26E-04
Uncertainty in mean average weight/particle (g):	9.19E-07

Dixie Barker
Operator

11-7-05
Date

Data Report Form DRF-31: Measurement of Open Porosity using a Mercury Porosimeter

Procedure:	AGR-CHAR-DAM-31 Rev. 0
Operator:	S. D. Nunn
Coated particle batch ID:	LEU01-15I-D01
Batch Description:	IPyC coated BWXT composite 69302
Thermocouple Expiration Date:	5/23/06
Penetrometer Expiration Date:	5/25/06
Completed DRF Filename:	\\mc-agr\AGR\Porosimeter\S05110801\S05110801_DRF31R0.xls

Mean average weight/particle (g):	4.26E-04
Uncertainty in mean average weight/particle (g):	9.19E-07

Weight of particles (g):	4.0001
Approximate number of particles:	9390
Uncertainty in number of particles:	20
Total envelope volume of sample (cc):	1.344
Average envelope volume/particle (cc):	1.43E-04
Sample envelope density (g/cc):	2.976

Average particle diameter (microns):	6.49E+02
Average surface area/particle (cm2):	1.32E-02
Total sample surface area (cm2):	1.24E+02
Intruded mercury volume from 250-10,000 psia (cc):	1.93E-02
Open porosity (ml/m2):	1.56E+00

S. D. Nunn
Operator

12/7/05
Date

12 Characterization of first batch of TRISO-coated particles

This section contains data on LEU03-03T, the first batch of TRISO-coated particles used for the LEU03-09T particle composite. The data was obtained according to product inspection plan AGR-CHAR-PIP-06R0.

Note that some of the carbon deposited for the buffer layer reacted with the kernel to form a uranium carbide layer between the kernel and the buffer. The uranium carbide layer was not included in the measurement of the buffer thickness. The thickness of this carbide layer varied, but was typically 4-5 μm thick and effectively increased the kernel radius by that amount.

The following pages show the inspection report form (IRF-06). Following IRF-06 are the individual data report forms for the measurements that were performed. Additional data at the end of this section is provided for information only. This batch was determined to satisfy the specifications in section 5.2 of EDF 6638, Rev. 1.

Inspection Report Form IRF-06: Coated Particle Batches

Procedure:	AGR-CHAR-PIP-06 Rev. 0
Coated particle batch ID:	LEU03-03T
Coated particle batch description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	k or t value	INL EDF-6638 Rev. 1				
Average buffer thickness for each particle (μm)	111.2	8.2	187	1.653	mean 100 ± 15	A = x - ts/√n ≥ 85	110.2	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 115	112.2	pass	
Average IPyC thickness for each particle (μm)	40.3	2.3	239	1.651	mean 40 ± 5	A = x - ts/√n ≥ 35	40.1	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 45	40.5	pass	
Average SiC thickness for each particle (μm)	33.5	1.1	239	1.651	mean 35 ± 4	A = x - ts/√n ≥ 31	33.4	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 39	33.6	pass	
Average OPyC thickness for each particle (μm)	42.7	2.1	239	1.651	mean 40 ± 5	A = x - ts/√n ≥ 35	42.5	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 45	42.9	pass	
Particles with missing OPyC			15534		defect fraction ≤ 6.0×10^{-4}	≤4 in 15,500	0	pass	DRF-19
OPyC sink/float density (Mg/m^3)	1.8929	0.0084	75	1.666	mean 1.90 ± 0.05	A = x - ts/√n ≥ 1.85	1.891	pass	DRF-03
						B = x + ts/√n ≤ 1.95	1.895	pass	
				2.743	dispersion ≤0.01 ≤ 1.80 ≤0.01 ≥ 2.00	C = x - ks > 1.80	1.870	pass	
						D = x + ks < 2.00	1.916	pass	

Comments

John Thomas
QC Supervisor

12-12-06
Date

Accept Coated particle batch (Yes or No):	Yes

Mark C. Lee
QA Reviewer

12/13/06
Date

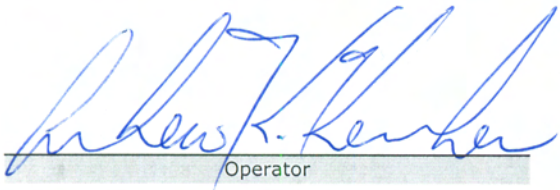
Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 2
Operator:	Andrew K. Kercher
Sample ID:	LEU03-03T-B01
Sample description:	AGR 3/4 driver TRISO on BWXT kernel composite 69303
Mount ID number:	M06091801L
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P06092201\P0609220101\

DMR calibration expiration date:	9/18/2007
Calibrated pixels/micron:	2.8280
Stage micrometer calibration expiration date:	2/17/2007
Measured value for 500 μm in stage micrometer image (μm):	500.0

Polish-down distance n,m (μm)			
2,2	2,8	8,2	8,8
371	358	386	367

Approximate layer width in polish plane (μm)				
Kernel radius	Buffer	IPyC	SiC	OPyC
172	122	40	35	39



Operator

September 22, 2006

Date

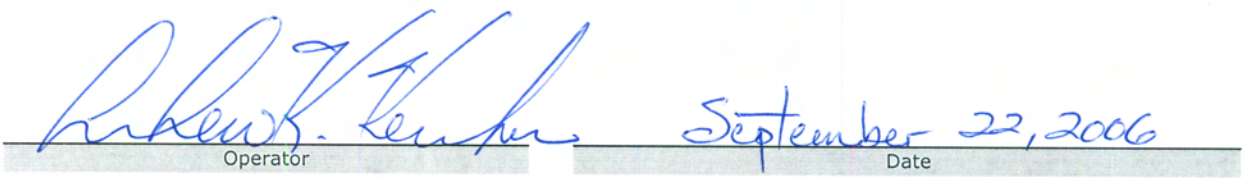
Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 2
Operator:	Andrew K. Kercher
Sample ID:	LEU03-03T-B01
Sample description:	AGR 3/4 driver TRISO on BWXT kernel composite 69303
Mount ID number:	M06091802L
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P06092201\P0609220102\

DMR calibration expiration date:	9/18/2007
Calibrated pixels/micron:	2.8280
Stage micrometer calibration expiration date:	2/17/2007
Measured value for 500 μm in stage micrometer image (μm):	500.0

Polish-down distance n,m (μm)			
2,2	2,8	8,2	8,8
355	356	339	341

Approximate layer width in polish plane (μm)				
Kernel radius	Buffer	IPyC	SiC	OPyC
173	108	40	36	48



Operator

Date

Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 2
Operator:	Andrew K. Kercher
Sample ID:	LEU03-03T-B01
Sample description:	AGR 3/4 driver TRISO on BWXT kernel composite 69303
Mount ID number:	M06091803L
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P06092201\P0609220103\

DMR calibration expiration date:	9/18/2007
Calibrated pixels/micron:	2.8280
Stage micrometer calibration expiration date:	2/17/2007
Measured value for 500 μm in stage micrometer image (μm):	500.0

Polish-down distance n,m (μm)			
2,2	2,8	8,2	8,8
389	390	353	349

Approximate layer width in polish plane (μm)				
Kernel radius	Buffer	IPyC	SiC	OPyC
177	104	43	36	42

Operator

Date

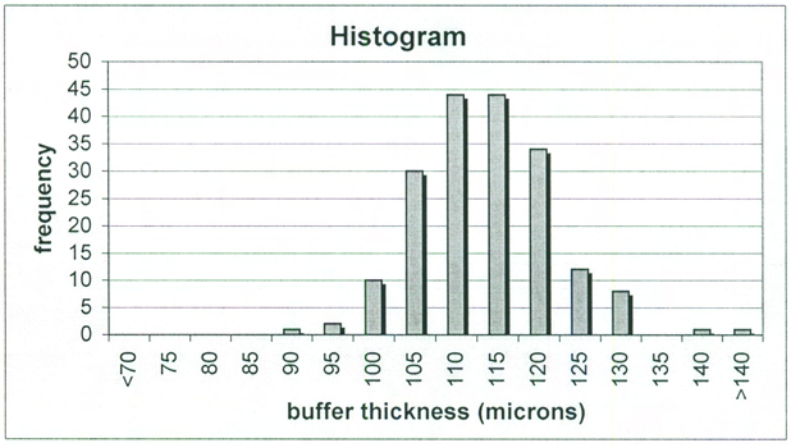
Data Report Form DRF-11A: Measurement of Buffer Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06092201\
Sample ID:	LEU03-03T-B01
Sample Description:	AGR 3/4 driver TRISO on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06092201_output\

Number of buffer layers analyzed:	187
Mean of the average buffer thickness of each particle (μm):	111.2
Standard deviation in the average buffer thickness of each particle (μm):	8.2

Distribution of the average buffer layer thickness (top binned)

Buffer Thickness (μm)	*Frequency*
<70	0
75	0
80	0
85	0
90	1
95	2
100	10
105	30
110	44
115	44
120	34
125	12
130	8
135	0
140	1
>140	1



Andrew K. Kercher
Operator

September 25, 2006
Date

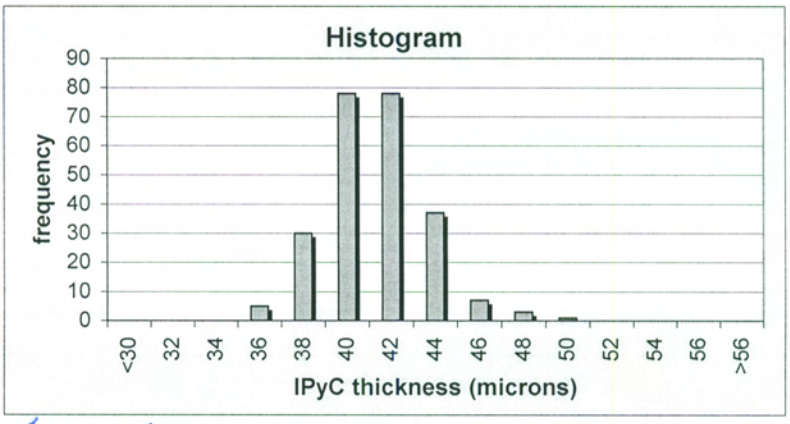
Data Report Form DRF-11B: Measurement of Inner Pyrocarbon Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06092201\
Sample ID:	LEU03-03T-B01
Sample Description:	AGR 3/4 driver TRISO on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06092201_output\

Number of inner pyrocarbon layers analyzed:	239
Mean of the average IPyC thickness of each particle (μm):	40.3
Standard deviation in the average IPyC thickness of each particle (μm):	2.3

Distribution of the average IPyC layer thickness (top binned)

IPyC Thickness (μm)	*Frequency*
<30	0
32	0
34	0
36	5
38	30
40	78
42	78
44	37
46	7
48	3
50	1
52	0
54	0
56	0
>56	0



Andrew K. Kercher — Operator

September 25, 2006 — Date

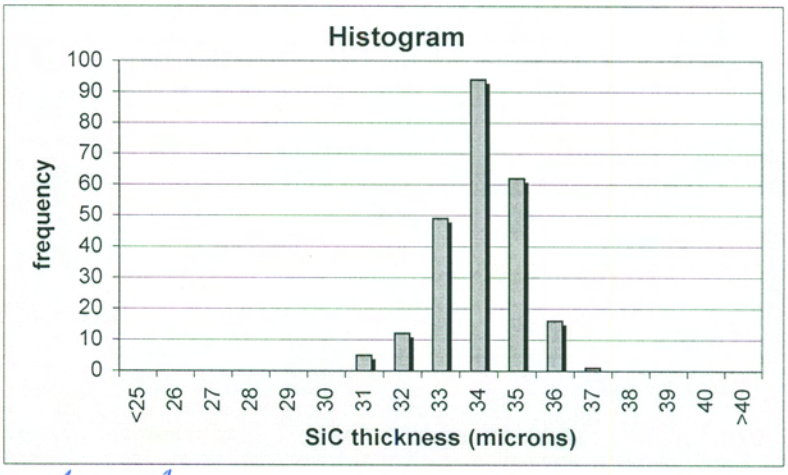
Data Report Form DRF-11C: Measurement of Silicon Carbide Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06092201\
Sample ID:	LEU03-03T-B01
Sample Description:	AGR 3/4 driver TRISO on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06092201_output\

Number of silicon carbide layers analyzed:	239
Mean of the average SiC thickness of each particle (μm):	33.5
Standard deviation in the average SiC thickness of each particle (μm):	1.1

Distribution of the average SiC layer thickness (top binned)

SiC Thickness (μm)	*Frequency*
<25	0
26	0
27	0
28	0
29	0
30	0
31	5
32	12
33	49
34	94
35	62
36	16
37	1
38	0
39	0
40	0
>40	0



Operator

September 25, 2006
Date

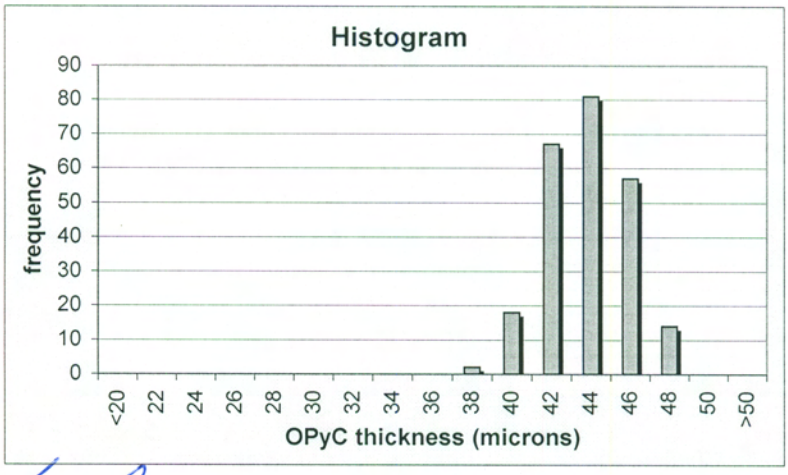
Data Report Form DRF-11D: Measurement of Outer Pyrocarbon Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06092201\
Sample ID:	LEU03-03T-B01
Sample Description:	AGR 3/4 driver TRISO on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06092201_output\

Number of outer pyrocarbon layers analyzed:	239
Mean of the average OPyC thickness of each particle (μm):	42.7
Standard deviation in the average OPyC thickness of each particle (μm):	2.1

Distribution of the average OPyC layer thickness (top binned)

OPyC Thickness (μm)	*Frequency*
<20	0
22	0
24	0
26	0
28	0
30	0
32	0
34	0
36	0
38	2
40	18
42	67
44	81
46	57
48	14
50	0
>50	0



Andrew K. Kercher
Operator

September 25, 2006
Date

Data Report Form DRF-19: Counting of Particles with Missing OPyC Layer by Visual Inspection

Procedure:	AGR-CHAR-DAM-19 Rev. 1
Operator:	John Hunn
Sample ID:	LEU03-03T-C01
Sample Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Filename:	\\mc-agr\AGR\MissingOPyC\X06120501_DRF19R1.xls

Mean average weight/particle (g):	7.83E-04
Uncertainty in average weight/particle (g):	7.46E-07
Weight of sample of particles (g):	12.163
Approximate number of particles in sample:	15534
Uncertainty in number of particles in sample:	15

Number of particles with missing OPyC layer:	0

Comments on unusual visual characteristics of OPyC

John Hunn — Operator

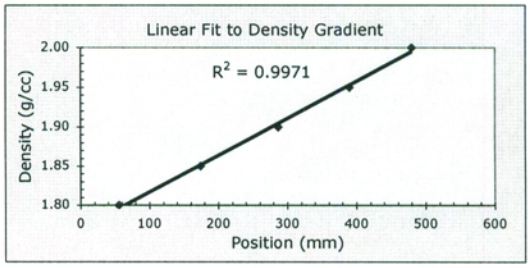
12-5-06 — Date

Data Report Form DRF-03: Measurement of PyC Density using a Density Gradient Column

Procedure:	AGR-CHAR-DAM-03 Rev. 2
Operator:	Dixie Barker
Filename:	\\mc-agr\AGR\DensityColumn\D06120701_DRF03R2.xls
Sample ID:	LEU03-03T-E01
Sample description:	OPyC fragments from AGR-3/4 driver TRISO on BWXT kernel composite 69303
Float expiration date:	07/2007
Gauge expiration date:	11/2007
Bath temperature:	23.2 °C

Calibrated Floats			
Density	Top of Float	Bottom of Float	Center of Mass
1.800	50.52	60.60	55.56
1.850	170.27	178.69	174.48
1.900	284.27	290.25	287.26
1.950	385.95	393.83	389.89
2.000	476.05	483.79	479.92

Linear Fit			
slope	StDev	intercept	StDev
4.70E-04	3.07E-06	1.77E+00	8.56E-04



Sample Density								
Fragment Number	Fragment Position	Calculated Density	Fragment Number	Fragment Position	Calculated Density	Fragment Number	Fragment Position	Calculated Density
1	212.09	1.8693	26	253.87	1.8889	51	270.63	1.8968
2	236.03	1.8805	27	255.00	1.8895	52	270.63	1.8968
3	238.23	1.8816	28	255.91	1.8899	53	270.69	1.8968
4	239.23	1.8820	29	258.91	1.8913	54	271.48	1.8972
5	237.22	1.8811	30	259.37	1.8915	55	272.49	1.8977
6	240.06	1.8824	31	259.37	1.8915	56	273.19	1.8980
7	239.41	1.8821	32	259.37	1.8915	57	274.26	1.8985
8	239.41	1.8821	33	260.29	1.8919	58	275.55	1.8991
9	240.32	1.8826	34	260.29	1.8919	59	275.55	1.8991
10	241.76	1.8832	35	261.42	1.8925	60	273.17	1.8980
11	241.18	1.8830	36	262.21	1.8928	61	276.65	1.8996
12	241.86	1.8833	37	262.21	1.8928	62	277.48	1.9000
13	242.89	1.8838	38	262.21	1.8928	63	278.56	1.9005
14	244.12	1.8843	39	263.04	1.8932	64	279.54	1.9010
15	244.89	1.8847	40	263.85	1.8936	65	279.54	1.9010
16	245.67	1.8851	41	263.85	1.8936	66	279.54	1.9010
17	247.09	1.8857	42	264.57	1.8940	67	282.12	1.9022
18	248.11	1.8862	43	265.14	1.8942	68	283.31	1.9028
19	248.78	1.8865	44	265.76	1.8945	69	284.90	1.9035
20	249.25	1.8868	45	266.52	1.8949	70	287.39	1.9047
21	249.81	1.8870	46	266.52	1.8949	71	289.53	1.9057
22	251.00	1.8876	47	267.99	1.8956	72	290.29	1.9060
23	252.06	1.8881	48	268.44	1.8958	73	291.69	1.9067
24	252.06	1.8881	49	269.03	1.8961	74	295.14	1.9083
25	252.78	1.8884	50	270.63	1.8968	75	324.06	1.9219

Average density of PyC fragments:	1.8929
Standard deviation in density of PyC fragments:	0.0084
Uncertainty in calculated density of PyC fragments:	0.0013

Dixie Barker
Operator

12-7-06
Date

For Information Only

The information in the remainder of this section reports results of measurements not required by the fuel specification and is provided for information only.

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	Dixie Barker
Particle Lot ID:	LEU03-03T
Particle Lot Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Filename:	\\mc-agr\AGR\ParticleWeight\W06091501_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	8.16E-02	1.04E-01	8.05E-02	9.14E-02	7.53E-02
Number of particles:	104	133	103	117	96
Average weight/particle (g):	7.85E-04	7.84E-04	7.82E-04	7.81E-04	7.84E-04

Mean average weight/particle (g):	7.83E-04
Standard error in mean average weight/particle (g):	7.46E-07

Dixie L Barker
Operator

9-15-06
Date

13 Characterization of second batch of TRISO-coated particles

This section contains data on LEU03-04T, the second batch of TRISO-coated particles used for the LEU03-09T particle composite. The data was obtained according to product inspection plan AGR-CHAR-PIP-06R0.

Note that some of the carbon deposited for the buffer layer reacted with the kernel to form a uranium carbide layer between the kernel and the buffer. The uranium carbide layer was not included in the measurement of the buffer thickness. The thickness of this carbide layer varied, but was typically 4-5 μm thick and effectively increased the kernel radius by that amount.

The following pages show the inspection report form (IRF-06). Following IRF-06 are the individual data report forms for the measurements that were performed. Additional data at the end of this section is provided for information only. This batch was determined to satisfy the specifications in section 5.2 of EDF 6638, Rev. 1.

Inspection Report Form IRF-06: Coated Particle Batches

Procedure:	AGR-CHAR-PIP-06 Rev. 0
Coated particle batch ID:	LEU03-04T
Coated particle batch description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	k or t value	INL EDF-6638 Rev. 1				
Average buffer thickness for each particle (μm)	109.1	8.6	204	1.652	mean 100 ± 15	A = x - ts/√n ≥ 85	108.1	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 115	110.1	pass	
Average IPyC thickness for each particle (μm)	39.8	2.1	229	1.652	mean 40 ± 5	A = x - ts/√n ≥ 35	39.6	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 45	40.0	pass	
Average SiC thickness for each particle (μm)	32.6	1.3	229	1.652	mean 35 ± 4	A = x - ts/√n ≥ 31	32.5	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 39	32.7	pass	
Average OPyC thickness for each particle (μm)	40.4	1.8	229	1.652	mean 40 ± 5	A = x - ts/√n ≥ 35	40.2	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 45	40.6	pass	
Particles with missing OPyC			15558		defect fraction ≤ 6.0 x 10^{-4}	≤4 in 15,500	0	pass	DRF-19
OPyC sink/float density (Mg/m^3)	1.9153	0.0070	49	1.677	mean 1.90 ± 0.05	A = x - ts/√n ≥ 1.85	1.914	pass	DRF-03
						B = x + ts/√n ≤ 1.95	1.917	pass	
				2.861	dispersion ≤0.01 ≤ 1.80 ≤0.01 ≥ 2.00	C = x - ks > 1.80	1.895	pass	
						D = x + ks < 2.00	1.935	pass	

Comments

QC Supervisor — Date: 12-12-06

Accept Coated particle batch (Yes or No):	Yes

QA Reviewer — Date: 12/13/06

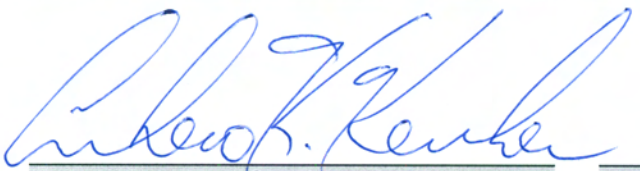
Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 2
Operator:	Andrew K. Kercher
Sample ID:	LEU03-04T-B01
Sample description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Mount ID number:	M06092701L
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P06100201\P0610020101\

DMR calibration expiration date:	9/18/2007
Calibrated pixels/micron:	2.8280
Stage micrometer calibration expiration date:	2/17/2007
Measured value for 500 µm in stage micrometer image (µm):	500.0

Polish-down distance n,m (µm)			
2,2	2,8	8,2	8,8
346	363	371	382

Approximate layer width in polish plane (µm)				
Kernel radius	Buffer	IPyC	SiC	OPyC
179	111	38	34	39



Operator

October 2, 2006

Date

Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 2
Operator:	Andrew K. Kercher
Sample ID:	LEU03-04T-B01
Sample description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Mount ID number:	M06092702L
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P06100201\P0610020102\

DMR calibration expiration date:	9/18/2007
Calibrated pixels/micron:	2.8280
Stage micrometer calibration expiration date:	2/17/2007
Measured value for 500 µm in stage micrometer image (µm):	500.0

Polish-down distance n,m (µm)			
2,2	2,8	8,2	8,8
381	352	420	400

Approximate layer width in polish plane (µm)				
Kernel radius	Buffer	IPyC	SiC	OPyC
181	111	40	36	42

Operator

Date

Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 2
Operator:	Andrew K. Kercher
Sample ID:	LEU03-04T-B01
Sample description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Mount ID number:	M06092703L
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P06100201\P0610020103\

DMR calibration expiration date:	9/18/2007
Calibrated pixels/micron:	2.8280
Stage micrometer calibration expiration date:	2/17/2007
Measured value for 500 µm in stage micrometer image (µm):	500.0

Polish-down distance n,m (µm)			
2,2	2,8	8,2	8,8
362	343	376	359

Approximate layer width in polish plane (µm)				
Kernel radius	Buffer	IPyC	SiC	OPyC
178	109	37	33	39

Operator

Date

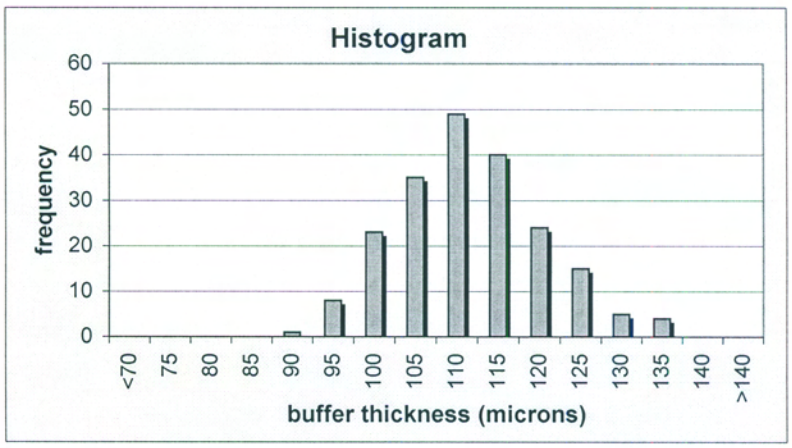
Data Report Form DRF-11A: Measurement of Buffer Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06100201\
Sample ID:	LEU03-04T-B01
Sample Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06100201_output\

Number of buffer layers analyzed:	204
Mean of the average buffer thickness of each particle (μm):	109.1
Standard deviation in the average buffer thickness of each particle (μm):	8.6

Distribution of the average buffer layer thickness (top binned)

Buffer Thickness (μm)	*Frequency*
<70	0
75	0
80	0
85	0
90	1
95	8
100	23
105	35
110	49
115	40
120	24
125	15
130	5
135	4
140	0
>140	0



Andrew K. Kercher
Operator

October 3, 2006
Date

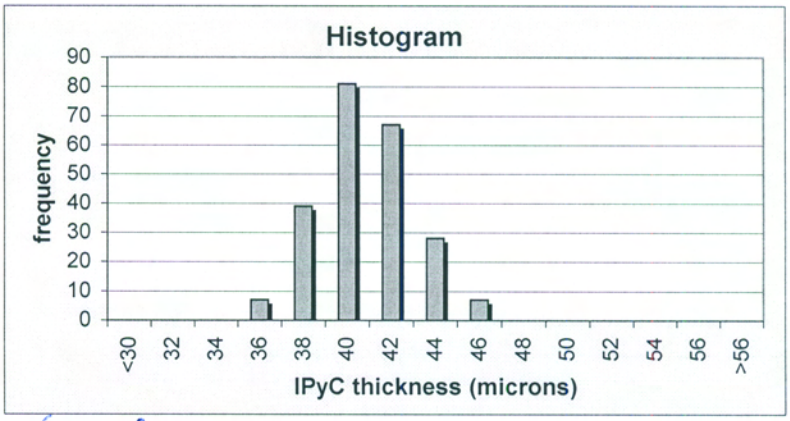
Data Report Form DRF-11B: Measurement of Inner Pyrocarbon Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06100201\
Sample ID:	LEU03-04T-B01
Sample Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06100201_output\

Number of inner pyrocarbon layers analyzed:	229
Mean of the average IPyC thickness of each particle (μm):	39.8
Standard deviation in the average IPyC thickness of each particle (μm):	2.1

Distribution of the average IPyC layer thickness (top binned)

IPyC Thickness (μm)	*Frequency*
<30	0
32	0
34	0
36	7
38	39
40	81
42	67
44	28
46	7
48	0
50	0
52	0
54	0
56	0
>56	0



Andrew K. Kercher — Operator

October 3, 2006 — Date

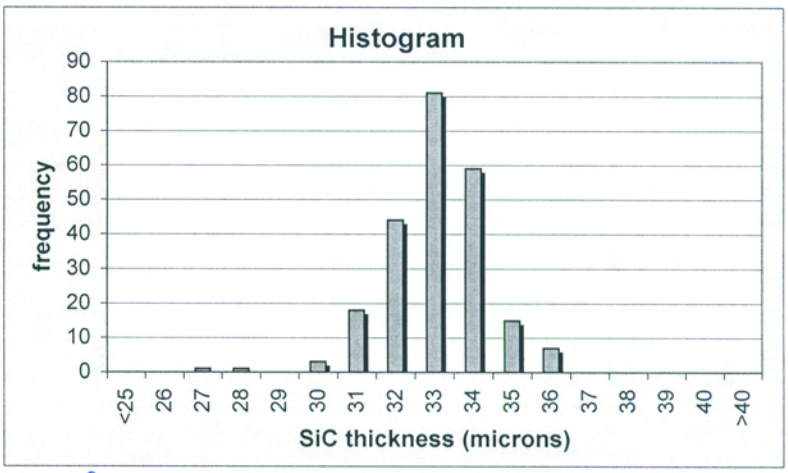
Data Report Form DRF-11C: Measurement of Silicon Carbide Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06100201\
Sample ID:	LEU03-04T-B01
Sample Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06100201_output\

Number of silicon carbide layers analyzed:	229
Mean of the average SiC thickness of each particle (μm):	32.6
Standard deviation in the average SiC thickness of each particle (μm):	1.3

Distribution of the average SiC layer thickness (top binned)

SiC Thickness (μm)	*Frequency*
<25	0
26	0
27	1
28	1
29	0
30	3
31	18
32	44
33	81
34	59
35	15
36	7
37	0
38	0
39	0
40	0
>40	0



Andrew K. Kercher
Operator

October 3, 2006
Date

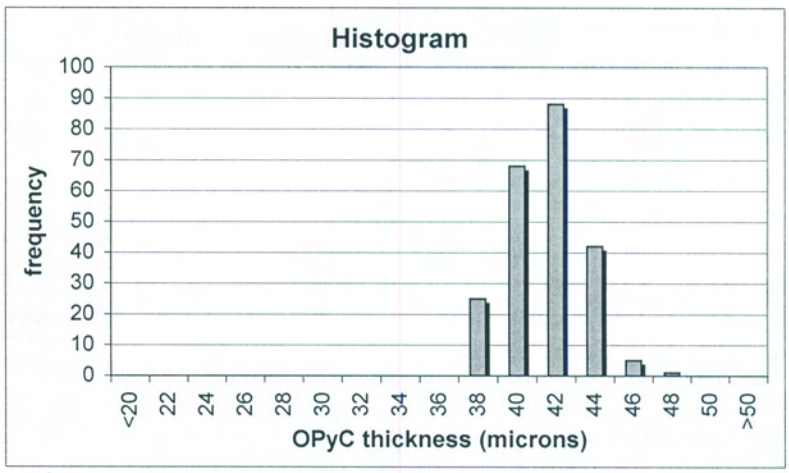
Data Report Form DRF-11D: Measurement of Outer Pyrocarbon Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06100201\
Sample ID:	LEU03-04T-B01
Sample Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06100201_output\

Number of outer pyrocarbon layers analyzed:	229
Mean of the average OPyC thickness of each particle (μm):	40.4
Standard deviation in the average OPyC thickness of each particle (μm):	1.8

Distribution of the average OPyC layer thickness (top binned)

OPyC Thickness (μm)	*Frequency*
<20	0
22	0
24	0
26	0
28	0
30	0
32	0
34	0
36	0
38	25
40	68
42	88
44	42
46	5
48	1
50	0
>50	0



Andrew K. Kercher
Operator

October 3, 2006
Date

Data Report Form DRF-19: Counting of Particles with Missing OPyC Layer by Visual Inspection

Procedure:	AGR-CHAR-DAM-19 Rev. 1
Operator:	John Hunn
Sample ID:	LEU03-04T-C01
Sample Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Filename:	\\mc-agr\AGR\MissingOPyC\X06120502_DRF19R1.xls

Mean average weight/particle (g):	7.70E-04
Uncertainty in average weight/particle (g):	9.90E-07
Weight of sample of particles (g):	11.980
Approximate number of particles in sample:	15558
Uncertainty in number of particles in sample:	20

Number of particles with missing OPyC layer:	0

Comments on unusual visual characteristics of OPyC

John Hunn — Operator

12-5-06 — Date

Data Report Form DRF-03: Measurement of PyC Density using a Density Gradient Column

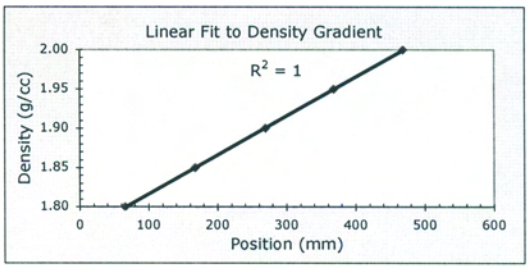
Procedure:	AGR-CHAR-DAM-03 Rev. 2
Operator:	Dixie Barker
Filename:	\\mc-agr\AGR\DensityColumn\D06120601_DRF03R2.xls
Sample ID:	LEU03-04T-E01
Sample description:	OPyC fragments from AGR-3/4 driver TRISO on BWXT kernel composite 69303
Float expiration date:	07/2007
Gauge expiration date:	11/2007
Bath temperature:	23.1 °C

Calibrated Floats

Density	Top of Float	Bottom of Float	Center of Mass
1.800	60.84	70.11	65.48
1.850	163.50	171.69	167.60
1.900	266.55	272.25	269.40
1.950	365.07	372.74	368.91
2.000	464.82	472.05	468.44

Linear Fit

slope	StDev	intercept	StDev
4.96E-04	3.09E-06	1.77E+00	8.35E-04



Sample Density

Fragment Number	Fragment Position	Calculated Density	Fragment Number	Fragment Position	Calculated Density	Fragment Number	Fragment Position	Calculated Density
1	277.33	1.9046	26	297.90	1.9149	51		
2	277.33	1.9046	27	299.45	1.9156	52		
3	280.91	1.9064	28	299.45	1.9156	53		
4	282.06	1.9070	29	300.41	1.9161	54		
5	282.77	1.9073	30	302.50	1.9171	55		
6	282.77	1.9073	31	303.28	1.9175	56		
7	282.10	1.9070	32	303.28	1.9175	57		
8	282.84	1.9074	33	305.63	1.9187	58		
9	283.15	1.9075	34	305.63	1.9187	59		
10	285.02	1.9085	35	306.93	1.9193	60		
11	285.68	1.9088	36	307.93	1.9198	61		
12	286.54	1.9092	37	308.88	1.9203	62		
13	286.45	1.9092	38	309.84	1.9208	63		
14	288.39	1.9101	39	309.84	1.9208	64		
15	289.42	1.9106	40	311.04	1.9214	65		
16	288.28	1.9101	41	311.04	1.9214	66		
17	289.94	1.9109	42	313.87	1.9228	67		
18	290.62	1.9112	43	313.87	1.9228	68		
19	293.29	1.9126	44	314.99	1.9233	69		
20	293.29	1.9126	45	318.92	1.9253	70		
21	294.35	1.9131	46	322.85	1.9272	71		
22	294.35	1.9131	47	325.36	1.9285	72		
23	295.17	1.9135	48	328.47	1.9300	73		
24	296.43	1.9141	49	335.51	1.9335	74		
25	297.90	1.9149	50			75		

Average density of PyC fragments:	1.9153
Standard deviation in density of PyC fragments:	0.0070
Uncertainty in calculated density of PyC fragments:	0.0013

Dixie Barker
Operator

12-6-06
Date

For Information Only

The information in the remainder of this section reports results of measurements not required by the fuel specification and is provided for information only.

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	Dixie Barler
Particle Lot ID:	LEU03-04T-D01
Particle Lot Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Filename:	\\mc-agr\AGR\ParticleWeight\W06092701_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	1.03E-01	8.09E-02	8.33E-02	8.48E-02	9.19E-02
Number of particles:	134	105	108	110	120
Average weight/particle (g):	7.69E-04	7.70E-04	7.71E-04	7.71E-04	7.66E-04

Mean average weight/particle (g):	7.70E-04
Standard error in mean average weight/particle (g):	9.90E-07

Dixie Barler
Operator

9-27-06
Date

14 Characterization of third batch of TRISO-coated particles

This section contains data on LEU03-05T, the third batch of TRISO-coated particles used for the LEU03-09T particle composite. The data was obtained according to product inspection plan AGR-CHAR-PIP-06R0.

Note that some of the carbon deposited for the buffer layer reacted with the kernel to form a uranium carbide layer between the kernel and the buffer. The uranium carbide layer was not included in the measurement of the buffer thickness. The thickness of this carbide layer varied, but was typically 4-5 μm thick and effectively increased the kernel radius by that amount.

The following pages show the inspection report form (IRF-06). Following IRF-06 are the individual data report forms for the measurements that were performed. Additional data at the end of this section is provided for information only. This batch was determined to satisfy the specifications in section 5.2 of EDF 6638, Rev. 1.

Inspection Report Form IRF-06: Coated Particle Batches

Procedure:	AGR-CHAR-PIP-06 Rev. 0
Coated particle batch ID:	LEU03-05T
Coated particle batch description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	k or t value	INL EDF-6638 Rev. 1				
Average buffer thickness for each particle (μm)	111.7	8.2	235	1.651	mean 100 ± 15	A = x - ts/√n ≥ 85	110.8	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 115	112.6	pass	
Average IPyC thickness for each particle (μm)	40.5	2.3	236	1.651	mean 40 ± 5	A = x - ts/√n ≥ 35	40.3	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 45	40.7	pass	
Average SiC thickness for each particle (μm)	32.9	1.1	236	1.651	mean 35 ± 4	A = x - ts/√n ≥ 31	32.8	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 39	33.0	pass	
Average OPyC thickness for each particle (μm)	41.5	1.9	236	1.651	mean 40 ± 5	A = x - ts/√n ≥ 35	41.3	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 45	41.7	pass	
Particles with missing OPyC			15553		defect fraction ≤ 6.0×10^{-4}	≤4 in 15,500	0	pass	DRF-19
OPyC sink/float density (Mg/m^3)	1.9029	0.0098	52	1.675	mean 1.90 ± 0.05	A = x - ts/√n ≥ 1.85	1.901	pass	DRF-03
						B = x + ts/√n ≤ 1.95	1.905	pass	
				2.842	dispersion ≤0.01 ≤ 1.80 ≤0.01 ≥ 2.00	C = x - ks > 1.80	1.875	pass	
						D = x + ks < 2.00	1.931	pass	

Comments

QC Supervisor — 12-12-06 — Date

Accept Coated particle batch (Yes or No):	Yes

QA Reviewer — 12/13/06 — Date

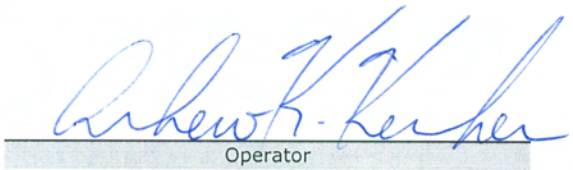
Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 2
Operator:	Andrew K. Kercher
Sample ID:	LEU03-05T-B01
Sample description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Mount ID number:	M06101801L
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P06102001\P0610200101\

DMR calibration expiration date:	9/18/2007
Calibrated pixels/micron:	2.8280
Stage micrometer calibration expiration date:	2/17/2007
Measured value for 500 µm in stage micrometer image (µm):	499.3

Polish-down distance n,m (µm)			
2,2	2,8	8,2	8,8
391	367	400	379

Approximate layer width in polish plane (µm)				
Kernel radius	Buffer	IPyC	SiC	OPyC
173	121	41	34	44



Operator

October 20, 2006

Date

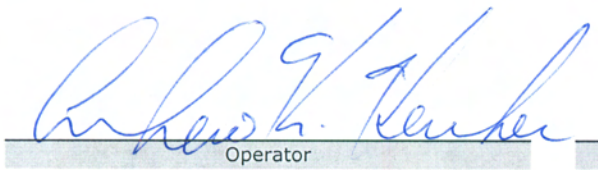
Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 2
Operator:	Andrew K. Kercher
Sample ID:	LEU03-05T-B01
Sample description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Mount ID number:	M06101802L
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P06102001\P0610200102\

DMR calibration expiration date:	9/18/2007
Calibrated pixels/micron:	2.8280
Stage micrometer calibration expiration date:	2/17/2007
Measured value for 500 µm in stage micrometer image (µm):	499.3

Polish-down distance n,m (µm)			
2,2	2,8	8,2	8,8
376	403	352	371

Approximate layer width in polish plane (µm)				
Kernel radius	Buffer	IPyC	SiC	OPyC
171	111	41	36	39



Operator

October 20, 2006

Date

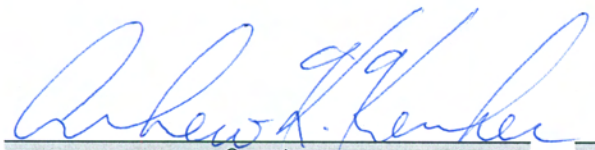
Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 2
Operator:	Andrew K. Kercher
Sample ID:	LEU03-05T-B01
Sample description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Mount ID number:	M06101803L
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P06102001\P0610200103\

DMR calibration expiration date:	9/18/2007
Calibrated pixels/micron:	2.8280
Stage micrometer calibration expiration date:	2/17/2007
Measured value for 500 μm in stage micrometer image (μm):	499.3

Polish-down distance n,m (μm)			
2,2	2,8	8,2	8,8
381	391	370	380

Approximate layer width in polish plane (μm)				
Kernel radius	Buffer	IPyC	SiC	OPyC
174	119	39	33	41



Operator

October 20, 2006

Date

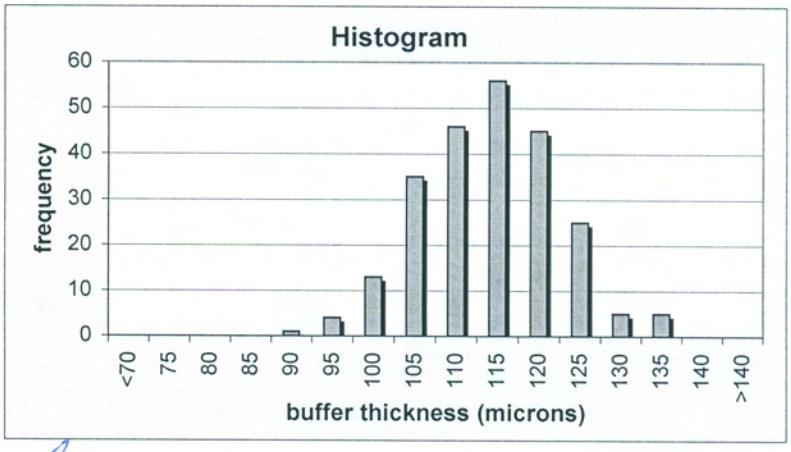
Data Report Form DRF-11A: Measurement of Buffer Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06102001\
Sample ID:	LEU03-05T-B01
Sample Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06102001_output\

Number of buffer layers analyzed:	235
Mean of the average buffer thickness of each particle (μm):	111.7
Standard deviation in the average buffer thickness of each particle (μm):	8.2

Distribution of the average buffer layer thickness (top binned)

Buffer Thickness (μm)	*Frequency*
<70	0
75	0
80	0
85	0
90	1
95	4
100	13
105	35
110	46
115	56
120	45
125	25
130	5
135	5
140	0
>140	0



Operator

November 6, 2006

Date

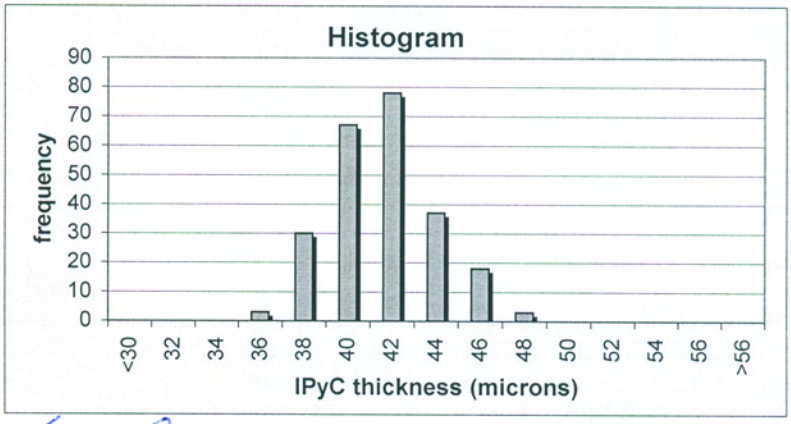
Data Report Form DRF-11B: Measurement of Inner Pyrocarbon Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06102001\
Sample ID:	LEU03-05T-B01
Sample Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06102001_output\

Number of inner pyrocarbon layers analyzed:	236
Mean of the average IPyC thickness of each particle (μm):	40.5
Standard deviation in the average IPyC thickness of each particle (μm):	2.3

Distribution of the average IPyC layer thickness (top binned)

IPyC Thickness (μm)	*Frequency*
<30	0
32	0
34	0
36	3
38	30
40	67
42	78
44	37
46	18
48	3
50	0
52	0
54	0
56	0
>56	0



Andrew K. Kercher
Operator

November 6, 2006
Date

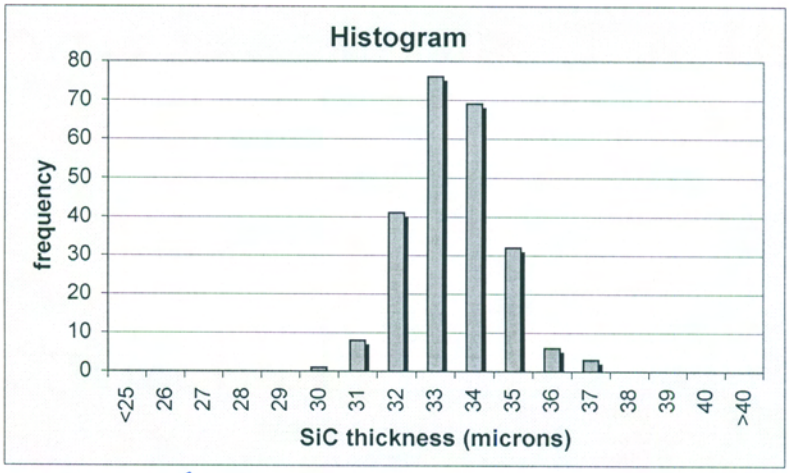
Data Report Form DRF-11C: Measurement of Silicon Carbide Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06102001\
Sample ID:	LEU03-05T-B01
Sample Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06102001_output\

Number of silicon carbide layers analyzed:	236
Mean of the average SiC thickness of each particle (μm):	32.9
Standard deviation in the average SiC thickness of each particle (μm):	1.1

Distribution of the average SiC layer thickness (top binned)

SiC Thickness (μm)	*Frequency*
<25	0
26	0
27	0
28	0
29	0
30	1
31	8
32	41
33	76
34	69
35	32
36	6
37	3
38	0
39	0
40	0
>40	0



Andrew K. Kercher — November 6, 2006

Operator — Date

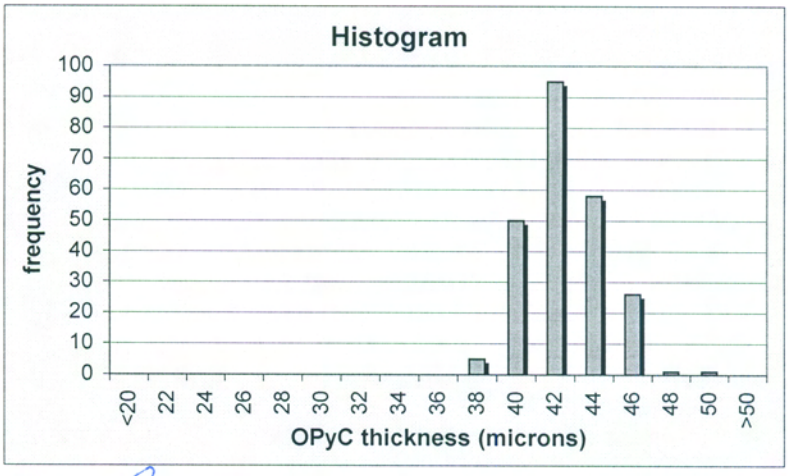
Data Report Form DRF-11D: Measurement of Outer Pyrocarbon Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06102001\
Sample ID:	LEU03-05T-B01
Sample Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06102001_output\

Number of outer pyrocarbon layers analyzed:	236
Mean of the average OPyC thickness of each particle (μm):	41.5
Standard deviation in the average OPyC thickness of each particle (μm):	1.9

Distribution of the average OPyC layer thickness (top binned)

OPyC Thickness (μm)	*Frequency*
<20	0
22	0
24	0
26	0
28	0
30	0
32	0
34	0
36	0
38	5
40	50
42	95
44	58
46	26
48	1
50	1
>50	0



Andrew K. Kercher — Operator

November 6, 2006 — Date

Data Report Form DRF-19: Counting of Particles with Missing OPyC Layer by Visual Inspection

Procedure:	AGR-CHAR-DAM-19 Rev. 1
Operator:	John Hunn
Sample ID:	LEU03-05T-C01
Sample Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Filename:	\\mc-agr\AGR\MissingOPyC\X06120503_DRF19R1.xls

Mean average weight/particle (g):	7.80E-04
Uncertainty in average weight/particle (g):	9.48E-07
Weight of sample of particles (g):	12.131
Approximate number of particles in sample:	15553
Uncertainty in number of particles in sample:	19

Number of particles with missing OPyC layer:	0

Comments on unusual visual characteristics of OPyC

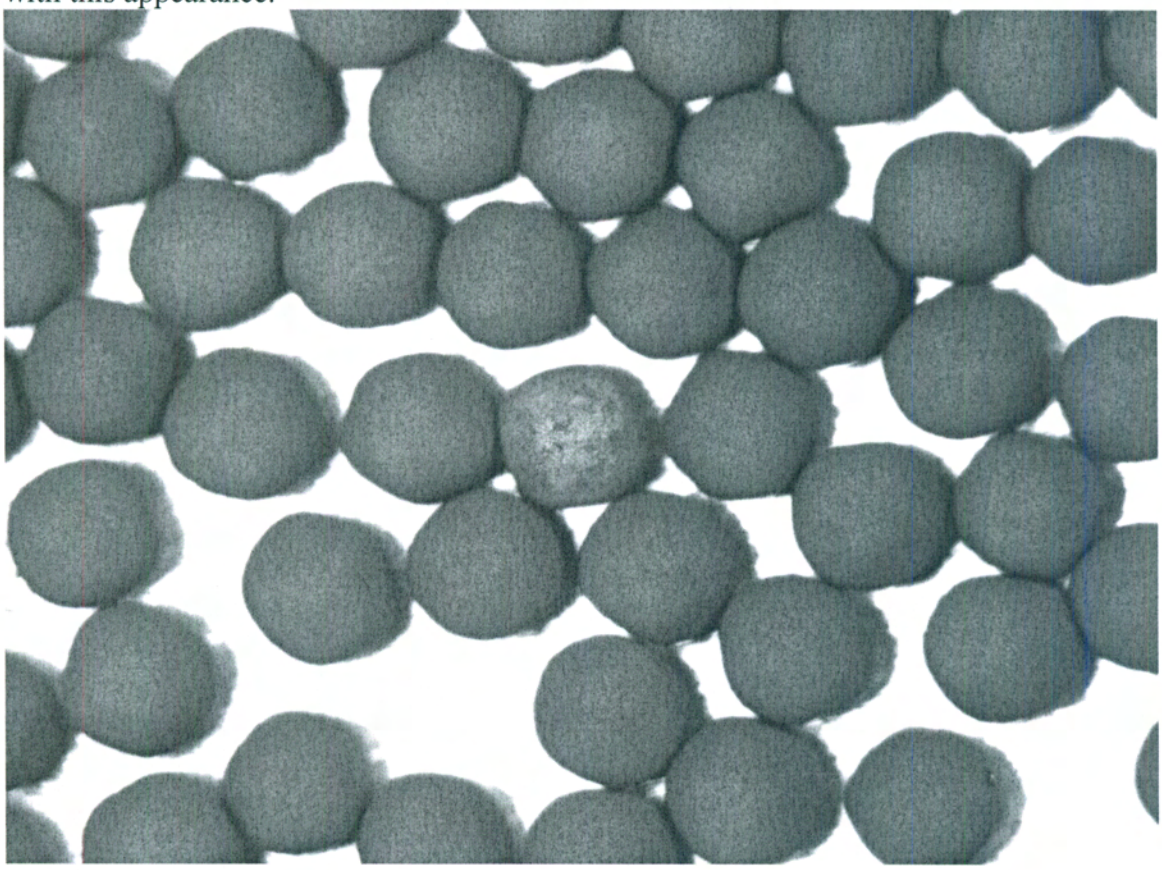
Observed 8 particle with mottled surface (image P0612050101.tif). Broke these particles to look at layers. The OPyC layers appeared to be of normal thickness. This anomaly was also observed on AGR-1 variant 1 particles and is reported in data compilation ORNL/TM-2006/020.

John Hunn — Operator

12-5-06 — Date

LEU03-05T-C01

Particle with unusual mottled gray OPyC surface appearance. 8 out of 15553 observed with this appearance.



Data Report Form DRF-03: Measurement of PyC Density using a Density Gradient Column

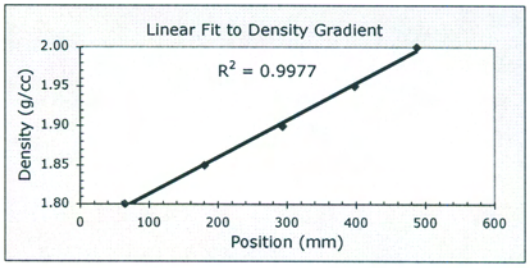
Procedure:	AGR-CHAR-DAM-03 Rev. 2
Operator:	Dixie Barker
Filename:	\\mc-agr\AGR\DensityColumn\D06121201_DRF03R2.xls
Sample ID:	LEU03-05T-E01
Sample description:	OPyC fragments from AGR-3/4 driver TRISO on BWXT kernel composite 69303
Float expiration date:	07/2007
Gauge expiration date:	11/2007
Bath temperature:	23.1 °C

Calibrated Floats

Density	Top of Float	Bottom of Float	Center of Mass
1.800	59.62	70.01	64.82
1.850	176.65	184.72	180.69
1.900	290.26	296.14	293.20
1.950	394.59	401.58	398.09
2.000	484.90	491.80	488.35

Linear Fit

slope	StDev	intercept	StDev
4.70E-04	2.86E-06	1.77E+00	8.79E-04



Sample Density

Fragment Number	Fragment Position	Calculated Density	Fragment Number	Fragment Position	Calculated Density	Fragment Number	Fragment Position	Calculated Density
1	240.15	1.8789	26	295.37	1.9049	51	319.95	1.9164
2	243.88	1.8807	27	296.31	1.9053	52	326.35	1.9194
3	246.83	1.8820	28	297.42	1.9058	53		
4	250.29	1.8837	29	298.11	1.9061	54		
5	256.26	1.8865	30	298.86	1.9065	55		
6	258.20	1.8874	31	298.86	1.9065	56		
7	268.70	1.8923	32	301.84	1.9079	57		
8	269.96	1.8929	33	302.85	1.9084	58		
9	271.30	1.8935	34	302.85	1.9084	59		
10	271.98	1.8939	35	303.51	1.9087	60		
11	275.73	1.8956	36	303.51	1.9087	61		
12	275.73	1.8956	37	304.83	1.9093	62		
13	277.57	1.8965	38	305.92	1.9098	63		
14	277.57	1.8965	39	306.53	1.9101	64		
15	280.32	1.8978	40	306.53	1.9101	65		
16	280.98	1.8981	41	307.31	1.9105	66		
17	282.68	1.8989	42	307.92	1.9108	67		
18	285.96	1.9004	43	308.85	1.9112	68		
19	286.58	1.9007	44	309.64	1.9116	69		
20	287.86	1.9013	45	311.21	1.9123	70		
21	288.43	1.9016	46	313.03	1.9132	71		
22	288.96	1.9018	47	313.84	1.9135	72		
23	289.36	1.9020	48	316.44	1.9148	73		
24	293.17	1.9038	49	317.16	1.9151	74		
25	294.68	1.9045	50	319.95	1.9164	75		

Average density of PyC fragments:	1.9029
Standard deviation in density of PyC fragments:	0.0098
Uncertainty in calculated density of PyC fragments:	0.0013

Dixie Barker
Operator

12-12-06
Date

For Information Only

The information in the remainder of this section reports results of measurements not required by the fuel specification and is provided for information only.

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	Dixie Barker
Particle Lot ID:	LEU03-05T
Particle Lot Description:	AGR3/4 driver TRISO on BWXT kernel composite 69303
Filename:	\\mc-agr\AGR\ParticleWeight\W06101801_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	9.19E-02	1.03E-01	1.01E-01	7.57E-02	9.06E-02
Number of particles:	118	131	130	97	116
Average weight/particle (g):	7.79E-04	7.83E-04	7.78E-04	7.80E-04	7.81E-04

Mean average weight/particle (g):	7.80E-04
Standard error in mean average weight/particle (g):	9.48E-07

Dixie Barker
Operator

10-18-06
Date

15 Characterization of fourth batch of TRISO-coated particles

This section contains data on LEU03-06T, the fourth batch of TRISO-coated particles used for the LEU03-09T particle composite. The data was obtained according to product inspection plan AGR-CHAR-PIP-06R0.

Note that some of the carbon deposited for the buffer layer reacted with the kernel to form a uranium carbide layer between the kernel and the buffer. The uranium carbide layer was not included in the measurement of the buffer thickness. The thickness of this carbide layer varied, but was typically 4-5 μm thick and effectively increased the kernel radius by that amount.

The following pages show the inspection report form (IRF-06). Following IRF-06 are the individual data report forms for the measurements that were performed. Additional data at the end of this section is provided for information only. This batch was determined to satisfy the specifications in section 5.2 of EDF 6638, Rev. 1.

Inspection Report Form IRF-06: Coated Particle Batches

Procedure:	AGR-CHAR-PIP-06 Rev. 0
Coated particle batch ID:	LEU03-06T
Coated particle batch description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	k or t value	INL EDF-6638 Rev. 1				
Average buffer thickness for each particle (μm)	113.4	8.1	232	1.651	mean 100 ± 15	A = x - ts/√n ≥ 85	112.5	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 115	114.3	pass	
Average IPyC thickness for each particle (μm)	39.9	2.2	237	1.651	mean 40 ± 5	A = x - ts/√n ≥ 35	39.7	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 45	40.1	pass	
Average SiC thickness for each particle (μm)	32.0	1.0	237	1.651	mean 35 ± 4	A = x - ts/√n ≥ 31	31.9	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 39	32.1	pass	
Average OPyC thickness for each particle (μm)	40.5	1.9	237	1.651	mean 40 ± 5	A = x - ts/√n ≥ 35	40.3	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 45	40.7	pass	
Particles with missing OPyC			15600		defect fraction ≤ 6.0×10^{-4}	≤4 in 15,500	0	pass	DRF-19
OPyC sink/float density (Mg/m^3)	1.8945	0.0057	41	1.684	mean 1.90 ± 0.05	A = x - ts/√n ≥ 1.85	1.893	pass	DRF-03
						B = x + ts/√n ≤ 1.95	1.896	pass	
				2.922	dispersion ≤0.01 ≤ 1.80 ≤0.01 ≥ 2.00	C = x - ks > 1.80	1.878	pass	
						D = x + ks < 2.00	1.911	pass	

Comments

QC Supervisor — 12-12-06 — Date

Accept Coated particle batch (Yes or No):	Yes

QA Reviewer — 12/13/06 — Date

Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 2
Operator:	Andrew K. Kercher
Sample ID:	LEU03-06T-B01
Sample description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Mount ID number:	M06101001L
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P06101201\P0610120101\

DMR calibration expiration date:	9/18/2007
Calibrated pixels/micron:	2.8280
Stage micrometer calibration expiration date:	2/17/2007
Measured value for 500 µm in stage micrometer image (µm):	500.0

Polish-down distance n,m (µm)			
2,2	2,8	8,2	8,8
395	376	378	360

Approximate layer width in polish plane (µm)				
Kernel radius	Buffer	IPyC	SiC	OPyC
179	113	39	33	39

Operator

Date

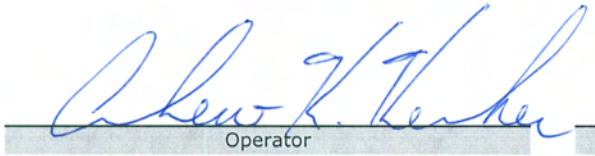
Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 2
Operator:	Andrew K. Kercher
Sample ID:	LEU03-06T-B01
Sample description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Mount ID number:	M06101002L
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P06101201\P0610120102\

DMR calibration expiration date:	9/18/2007
Calibrated pixels/micron:	2.8280
Stage micrometer calibration expiration date:	2/17/2007
Measured value for 500 µm in stage micrometer image (µm):	500.0

Polish-down distance n,m (µm)			
2,2	2,8	8,2	8,8
393	375	369	346

Approximate layer width in polish plane (µm)				
Kernel radius	Buffer	IPyC	SiC	OPyC
180	117	38	34	40



Operator

October 12, 2006

Date

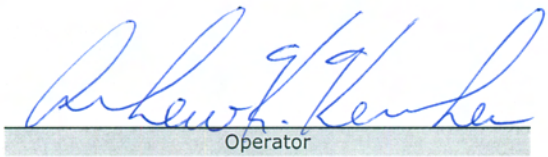
Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 2
Operator:	Andrew K. Kercher
Sample ID:	LEU03-06T-B01
Sample description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Mount ID number:	M06101003L
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P06101201\P0610120103\

DMR calibration expiration date:	9/18/2007
Calibrated pixels/micron:	2.8280
Stage micrometer calibration expiration date:	2/17/2007
Measured value for 500 µm in stage micrometer image (µm):	500.0

Polish-down distance n,m (µm)			
2,2	2,8	8,2	8,8
389	377	392	404

Approximate layer width in polish plane (µm)				
Kernel radius	Buffer	IPyC	SiC	OPyC
177	115	37	33	37



Operator

October 12, 2006

Date

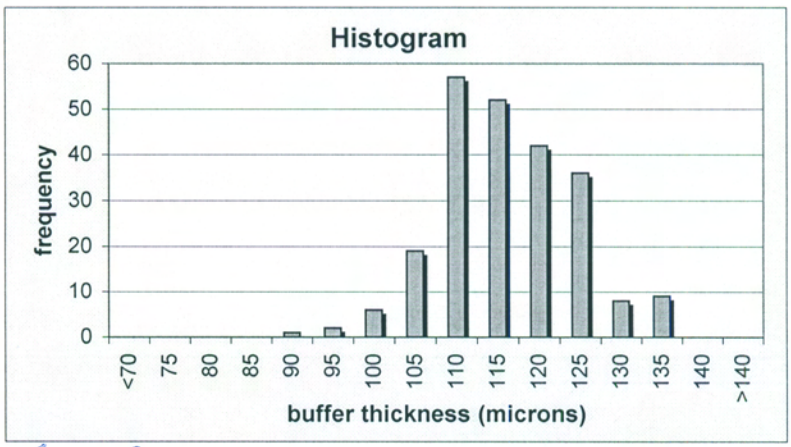
Data Report Form DRF-11A: Measurement of Buffer Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06101201\
Sample ID:	LEU03-06T-B01
Sample Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06101201_output\

Number of buffer layers analyzed:	232
Mean of the average buffer thickness of each particle (μm):	113.4
Standard deviation in the average buffer thickness of each particle (μm):	8.1

Distribution of the average buffer layer thickness (top binned)

Buffer Thickness (μm)	*Frequency*
<70	0
75	0
80	0
85	0
90	1
95	2
100	6
105	19
110	57
115	52
120	42
125	36
130	8
135	9
140	0
>140	0



Andrew K. Kercher
Operator

October 16, 2006
Date

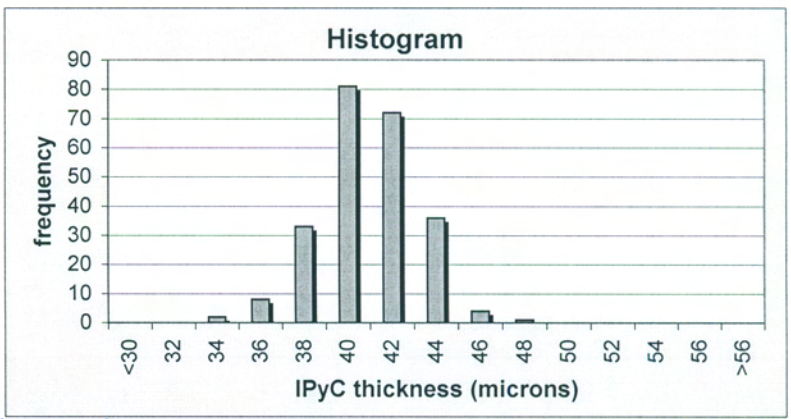
Data Report Form DRF-11B: Measurement of Inner Pyrocarbon Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06101201\
Sample ID:	LEU03-06T-B01
Sample Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06101201_output\

Number of inner pyrocarbon layers analyzed:	237
Mean of the average IPyC thickness of each particle (μm):	39.9
Standard deviation in the average IPyC thickness of each particle (μm):	2.2

Distribution of the average IPyC layer thickness (top binned)

IPyC Thickness (μm)	*Frequency*
<30	0
32	0
34	2
36	8
38	33
40	81
42	72
44	36
46	4
48	1
50	0
52	0
54	0
56	0
>56	0



Andrew K. Kercher
Operator

October 16, 2006
Date

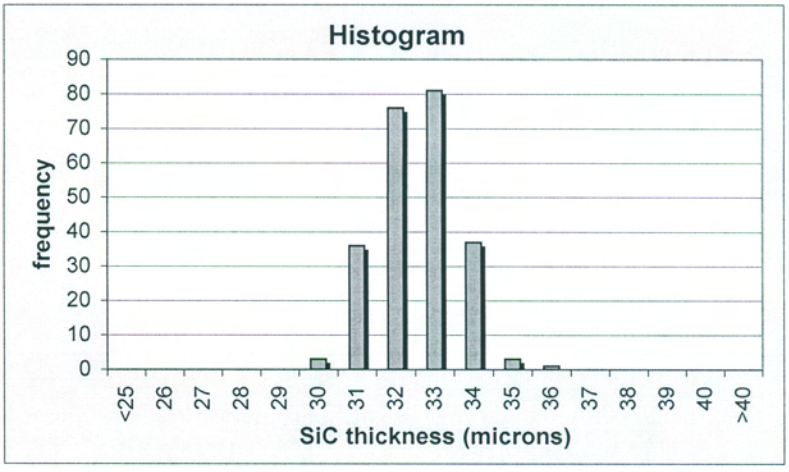
Data Report Form DRF-11C: Measurement of Silicon Carbide Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06101201\
Sample ID:	LEU03-06T-B01
Sample Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06101201_output\

Number of silicon carbide layers analyzed:	237
Mean of the average SiC thickness of each particle (μm):	32.0
Standard deviation in the average SiC thickness of each particle (μm):	1.0

Distribution of the average SiC layer thickness (top binned)

SiC Thickness (μm)	*Frequency*
<25	0
26	0
27	0
28	0
29	0
30	3
31	36
32	76
33	81
34	37
35	3
36	1
37	0
38	0
39	0
40	0
>40	0



Andrew K. Kercher — Operator

October 16, 2006 — Date

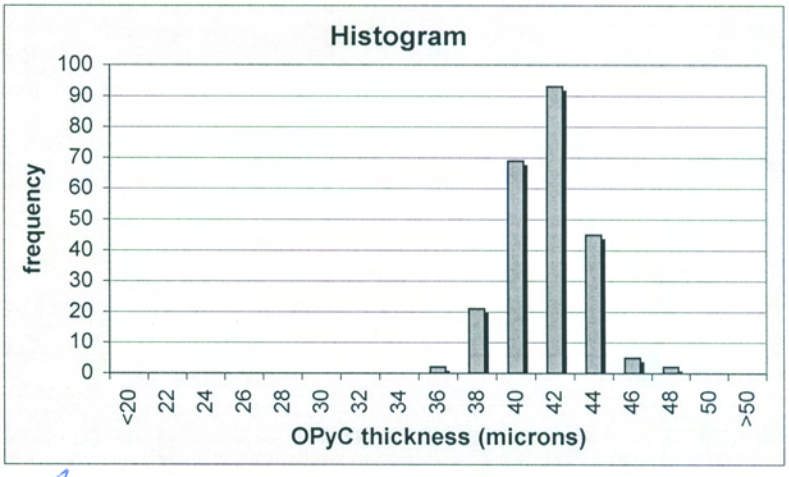
Data Report Form DRF-11D: Measurement of Outer Pyrocarbon Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06101201\
Sample ID:	LEU03-06T-B01
Sample Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P06101201_output\

Number of outer pyrocarbon layers analyzed:	237
Mean of the average OPyC thickness of each particle (μm):	40.5
Standard deviation in the average OPyC thickness of each particle (μm):	1.9

Distribution of the average OPyC layer thickness (top binned)

OPyC Thickness (μm)	*Frequency*
<20	0
22	0
24	0
26	0
28	0
30	0
32	0
34	0
36	2
38	21
40	69
42	93
44	45
46	5
48	2
50	0
>50	0



Operator

October 16, 2006

Date

Data Report Form DRF-19: Counting of Particles with Missing OPyC Layer by Visual Inspection

Procedure:	AGR-CHAR-DAM-19 Rev. 1
Operator:	John Hunn
Sample ID:	LEU03-06T-C01
Sample Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Filename:	\\mc-agr\AGR\MissingOPyC\X06120504_DRF19R1.xls

Mean average weight/particle (g):	7.75E-04
Uncertainty in average weight/particle (g):	9.01E-07
Weight of sample of particles (g):	12.090
Approximate number of particles in sample:	15600
Uncertainty in number of particles in sample:	18

Number of particles with missing OPyC layer:	0

Comments on unusual visual characteristics of OPyC

Observed 5 particles with mottled surface. See results for LEU03-05T for similar observation. OPyC on these particles is normal thickness.

John Hunn — Operator

12-5-06 — Date

Data Report Form DRF-03: Measurement of PyC Density using a Density Gradient Column

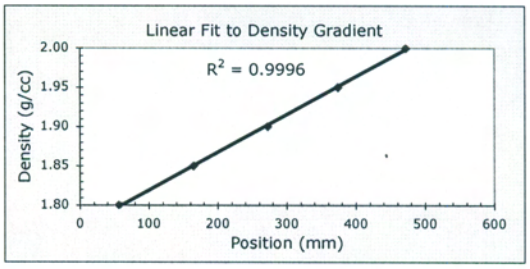
Procedure:	AGR-CHAR-DAM-03 Rev. 2
Operator:	Dixie Barker
Filename:	\\mc-agr\AGR\DensityColumn\D06121202_DRF03R2.xls
Sample ID:	LEU03-06T-E01
Sample description:	OPyC fragments from AGR-3/4 driver TRISO on BWXT kernel composite 69303
Float expiration date:	07/2007
Gauge expiration date:	11/2007
Bath temperature:	23.2 °C

Calibrated Floats

Density	Top of Float	Bottom of Float	Center of Mass
1.800	52.33	61.43	56.88
1.850	160.95	169.30	165.13
1.900	269.13	274.81	271.97
1.950	370.32	377.04	373.68
2.000	469.27	475.49	472.38

Linear Fit

slope	StDev	intercept	StDev
4.70E-04	3.07E-06	1.77E+00	8.56E-04



Sample Density

Fragment Number	Fragment Position	Calculated Density	Fragment Number	Fragment Position	Calculated Density	Fragment Number	Fragment Position	Calculated Density
1	243.74	1.8842	26	271.88	1.8974	51		
2	244.76	1.8846	27	272.48	1.8977	52		
3	247.78	1.8861	28	274.10	1.8984	53		
4	248.43	1.8864	29	275.35	1.8990	54		
5	250.35	1.8873	30	275.35	1.8990	55		
6	251.17	1.8877	31	276.25	1.8994	56		
7	252.33	1.8882	32	277.05	1.8998	57		
8	251.81	1.8880	33	277.60	1.9001	58		
9	254.48	1.8892	34	278.10	1.9003	59		
10	254.80	1.8894	35	280.04	1.9012	60		
11	256.15	1.8900	36	280.79	1.9016	61		
12	256.92	1.8904	37	287.38	1.9047	62		
13	257.77	1.8908	38	287.81	1.9049	63		
14	259.04	1.8914	39	280.76	1.9016	64		
15	259.49	1.8916	40	275.67	1.8992	65		
16	259.96	1.8918	41	280.59	1.9015	66		
17	262.03	1.8928	42			67		
18	263.12	1.8933	43			68		
19	265.48	1.8944	44			69		
20	265.82	1.8945	45			70		
21	265.82	1.8945	46			71		
22	266.68	1.8950	47			72		
23	267.42	1.8953	48			73		
24	267.42	1.8953	49			74		
25	268.92	1.8960	50			75		

Average density of PyC fragments:	1.8945
Standard deviation in density of PyC fragments:	0.0057
Uncertainty in calculated density of PyC fragments:	0.0012

Dixie Barker
Operator

12-12-06
Date

For Information Only

The information in the remainder of this section reports results of measurements not required by the fuel specification and is provided for information only.

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	Dixie Barker
Particle Lot ID:	LEU01-06T-D01
Particle Lot Description:	AGR-3/4 driver TRISO on BWXT kernel composite 69303
Filename:	\\mc-agr\AGR\ParticleWeight\W06101001_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	7.76E-02	1.14E-01	9.22E-02	9.43E-02	9.04E-02
Number of particles:	100	146	119	122	117
Average weight/particle (g):	7.76E-04	7.77E-04	7.75E-04	7.73E-04	7.73E-04

Mean average weight/particle (g):	7.75E-04
Standard error in mean average weight/particle (g):	9.01E-07

Dixie Barker
Operator

10-10-06
Date

16 Characterization of TRISO-coated particle composite

This section contains data on the TRISO-coated particle composite, LEU03-09T. The data was obtained according to product inspection plan AGR-CHAR-PIP-07R0.

Note that some of the carbon deposited for the buffer layer reacted with the kernel to form a uranium carbide layer between the kernel and the buffer. The uranium carbide layer was not included in the measurement of the buffer thickness. The thickness of this carbide layer varied, but was typically 4-5 μm thick and effectively increased the kernel radius by that amount.

The following pages shows the inspection report form (IRF-07) for the LEU03-09T composite. Following IRF-07 are the individual data report forms for the measurements that were performed. Additional data at the end of this section is provided for information only. This composite was determined to satisfy the specifications in section 5.3 of EDF 6638, Rev. 1.

Inspection Report Form IRF-07: Coated Particle Composites

Procedure:	AGR-CHAR-PIP-07 Rev. 0
Coated particle composite ID:	LEU03-09T
Coated particle composite description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303

Property	Measured Data				Specification	Acceptance Criteria	Acceptance Test Value	Pass or fail	Data Records
	Mean (x)	Std. Dev. (s)	# measured (n)	k or t value	INL EDF-6638 Rev. 1				
Average buffer thickness for each particle (μm)	109.7	7.7	192	1.653	mean 100 ± 15	A = x - ts/√n ≥ 85	108.8	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 115	110.6	pass	
				2.573	dispersion ≤0.01 ≤ 55	C = x - ks > 55	89.9	pass	
Average IPyC thickness for each particle (μm)	40.4	2.3	226	1.652	mean 40 ± 4	A = x - ts/√n ≥ 36	40.1	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 44	40.7	pass	
				2.552	dispersion ≤0.01 ≤ 30 ≤0.01 ≥ 56	C = x - ks > 30	34.5	pass	
						D = x + ks < 56	46.3	pass	
Average SiC thickness for each particle (μm)	33.5	1.1	227	1.652	mean 35 ± 3	A = x - ts/√n ≥ 32	33.4	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 38	33.6	pass	
				2.552	dispersion ≤0.01 ≤ 25	C = x - ks > 25	30.7	pass	
Average OPyC thickness for each particle (μm)	41.3	2.1	227	1.652	mean 40 ± 4	A = x - ts/√n ≥ 36	41.1	pass	DRF-08 DRF-11
						B = x + ts/√n ≤ 44	41.5	pass	
				2.552	dispersion ≤0.01 ≤ 20	C = x - ks > 20	35.9	pass	
Buffer envelope density	See IRF-02A							pass	IRF-02A
IPyC sink/float density	See IRF-02B							pass	IRF-02B
SiC sink/float density (Mg/m³)	3.2026	0.0024	50	1.677	mean ≥ 3.19	A = x - ts/√n ≥ 3.19	3.202	pass	DRF-02
				2.863	dispersion ≤0.01 ≤ 3.17	C = x - ks > 3.17	3.196	pass	
IPyC anisotropy (BAFo equivalent)	1.027	0.002	10	1.833	mean ≤ 1.035	B = x + ts/√n ≤ 1.035	1.028	pass	DRF-18
				3.981	dispersion ≤0.01 ≥1.06	D = x + ks < 1.06	1.035	pass	
OPyC anisotropy (BAFo equivalent)	1.021	0.002	10	1.833	mean ≤ 1.035	B = x + ts/√n ≤ 1.035	1.022	pass	DRF-18
				3.981	dispersion ≤0.01 ≥1.06	D = x + ks < 1.06	1.029	pass	
Particles with SiC gold spot defects			43040		defect fraction ≤ 1.0×10^{-3}	≤6 in 12,000 or ≤14 in 22,000	32	pass	DRF-20
Particle aspect ratio			1584		dispersion ≤0.01 ≥1.14	≤1 in 500 or ≤7 in 1420	1	pass	DRF-07 DRF-10
Particles with missing OPyC			31089		defect fraction ≤ 3.0×10^{-4}	≤4 in 31,000	0	pass	DRF-19
SiC microstructure			3		comparison to visual standard	all imaged pass visual standard comparison	3	pass	DRF-23

Comments

Buffer and IPyC coating conditions for all batches in composite satisfied criteria in Table 5.3 footnote c of EDF-6638, Rev. 1.
32 out of 43040 gold spot defects passes the acceptance criterion of ≤32 in 42977 indicating ≤1E-3 defects with 95% confidence.
NCR-X-AGR-07-01 was issued to document the use of a furnace controller overdue for calibration verification, data was not affected.
NCR-X-AGR-07-02 was issued to document a 7 μm discrepancy between roller micrometer upper diameter control limit and specified value.

John Kim
QC Supervisor

3-12-07
Date

Accept coated particle composite (Yes or No):	Yes

M C Lee
QA Reviewer

3/12/07
Date

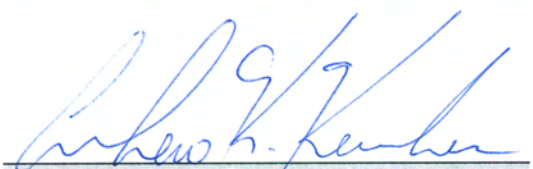
Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 2
Operator:	Andrew K. Kercher
Sample ID:	LEU03-09T-B01
Sample description:	AGR3/4 driver TRISO composite on BWXT kernel composite 69303
Mount ID number:	M07011001L
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P07020601\P0702060101\

DMR calibration expiration date:	9/18/2007
Calibrated pixels/micron:	2.8280
Stage micrometer calibration expiration date:	2/17/2007
Measured value for 500 µm in stage micrometer image (µm):	500.4

Polish-down distance n,m (µm)			
2,2	2,8	8,2	8,8
406	398	406	401

Approximate layer width in polish plane (µm)				
Kernel radius	Buffer	IPyC	SiC	OPyC
178	114	40	35	40



Operator

February 6, 2007

Date

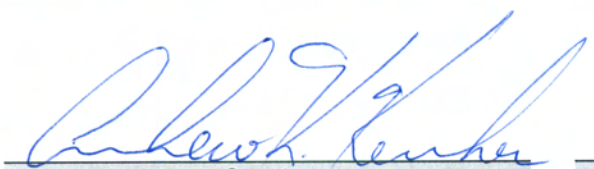
Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 2
Operator:	Andrew K. Kercher
Sample ID:	LEU03-09T-B01
Sample description:	AGR3/4 driver TRISO composite on BWXT kernel composite 69303
Mount ID number:	M07011002L
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P07020601\P0702060102\

DMR calibration expiration date:	9/18/2007
Calibrated pixels/micron:	2.8280
Stage micrometer calibration expiration date:	2/17/2007
Measured value for 500 µm in stage micrometer image (µm):	500.4

Polish-down distance n,m (µm)			
2,2	2,8	8,2	8,8
393	385	385	371

Approximate layer width in polish plane (µm)				
Kernel radius	Buffer	IPyC	SiC	OPyC
178	111	42	35	40



Operator

February 6, 2007

Date

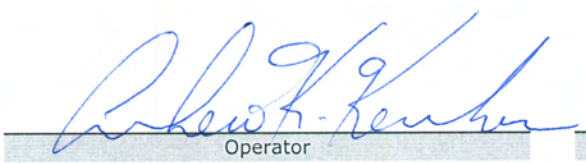
Data Report Form DRF-08: Imaging of Coated Particle Cross-sections Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-08 Rev. 2
Operator:	Andrew K. Kercher
Sample ID:	LEU03-09T-B01
Sample description:	AGR3/4 driver TRISO composite on BWXT kernel composite 69303
Mount ID number:	M07011601L
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P07020601\P0702060103\

DMR calibration expiration date:	9/18/2007
Calibrated pixels/micron:	2.8280
Stage micrometer calibration expiration date:	2/17/2007
Measured value for 500 µm in stage micrometer image (µm):	500.4

Polish-down distance n,m (µm)			
2,2	2,8	8,2	8,8
395	403	406	413

Approximate layer width in polish plane (µm)				
Kernel radius	Buffer	IPyC	SiC	OPyC
185	106	40	35	45



Operator

February 6, 2007

Date

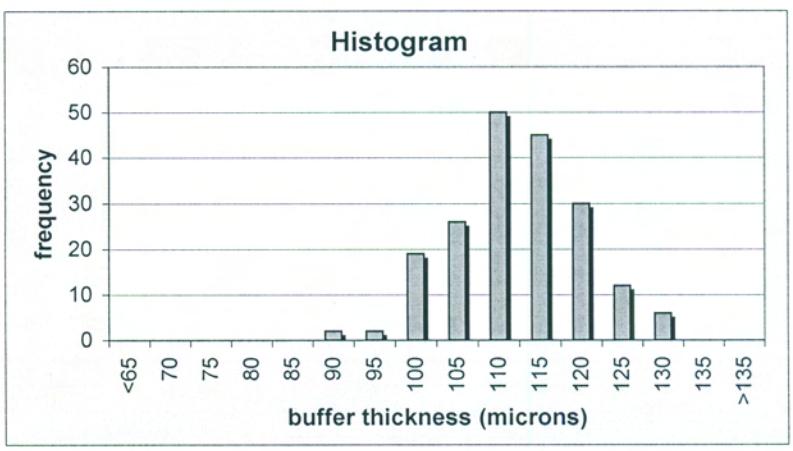
Data Report Form DRF-11A: Measurement of Buffer Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P07020601\
Sample ID:	LEU03-09T-B01
Sample Description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P07020601_output\

Number of buffer layers analyzed:	192
Mean of the average buffer thickness of each particle (μm):	109.7
Standard deviation in the average buffer thickness of each particle (μm):	7.7

Distribution of the average buffer layer thickness (top binned)

Buffer Thickness (μm)	*Frequency*
<65	0
70	0
75	0
80	0
85	0
90	2
95	2
100	19
105	26
110	50
115	45
120	30
125	12
130	6
135	0
>135	0



Andrew K. Kercher
Operator

February 7, 2007
Date

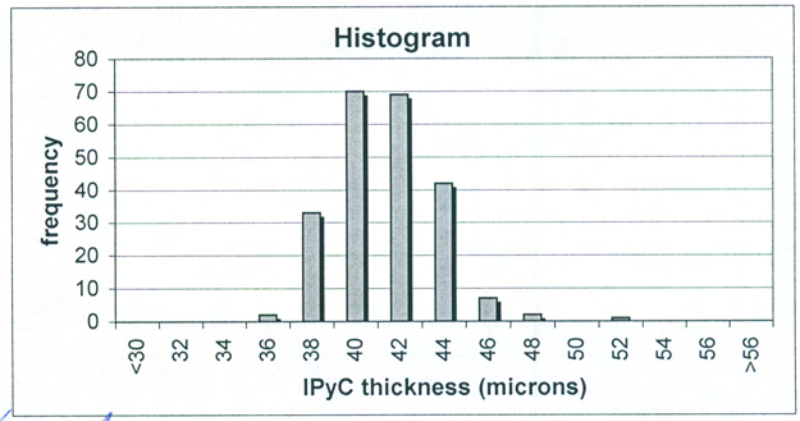
Data Report Form DRF-11B: Measurement of Inner Pyrocarbon Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P07020601\
Sample ID:	LEU03-09T-B01
Sample Description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P07020601_output\

Number of inner pyrocarbon layers analyzed:	226
Mean of the average IPyC thickness of each particle (μm):	40.4
Standard deviation in the average IPyC thickness of each particle (μm):	2.3

Distribution of the average IPyC layer thickness (top binned)

IPyC Thickness (μm)	*Frequency*
<30	0
32	0
34	0
36	2
38	33
40	70
42	69
44	42
46	7
48	2
50	0
52	1
54	0
56	0
>56	0



Andrew K. Kercher
Operator

February 7, 2007
Date

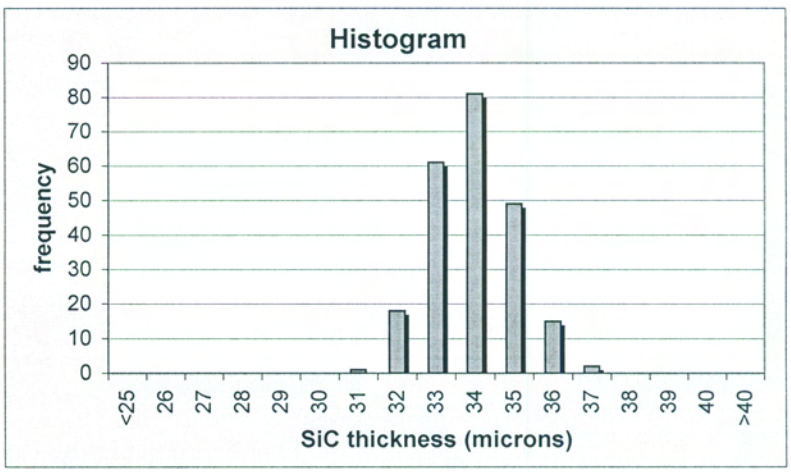
Data Report Form DRF-11C: Measurement of Silicon Carbide Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P07020601\
Sample ID:	LEU03-09T-B01
Sample Description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P07020601_output\

Number of silicon carbide layers analyzed:	227
Mean of the average SiC thickness of each particle (μm):	33.5
Standard deviation in the average SiC thickness of each particle (μm):	1.1

Distribution of the average SiC layer thickness (top binned)

SiC Thickness (μm)	*Frequency*
<25	0
26	0
27	0
28	0
29	0
30	0
31	1
32	18
33	61
34	81
35	49
36	15
37	2
38	0
39	0
40	0
>40	0



Operator

February 7, 2007
Date

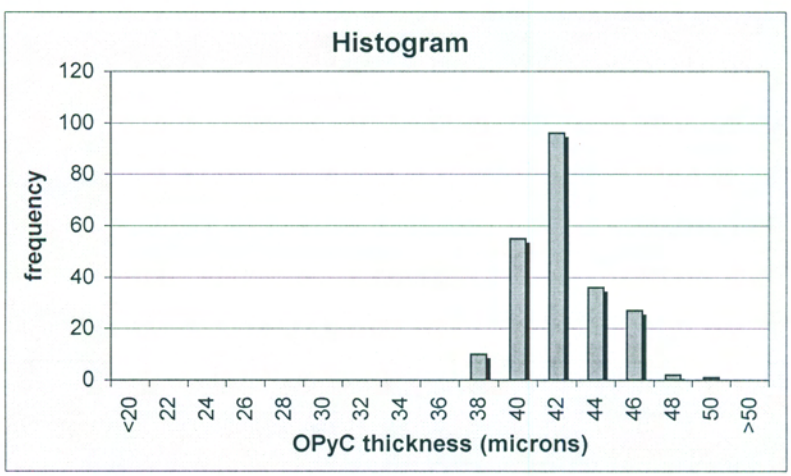
Data Report Form DRF-11D: Measurement of Outer Pyrocarbon Layer Thickness

Procedure:	AGR-CHAR-DAM-11 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P07020601\
Sample ID:	LEU03-09T-B01
Sample Description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Layers\P07020601_output\

Number of outer pyrocarbon layers analyzed:	227
Mean of the average OPyC thickness of each particle (μm):	41.3
Standard deviation in the average OPyC thickness of each particle (μm):	2.1

Distribution of the average OPyC layer thickness (top binned)

OPyC Thickness (μm)	*Frequency*
<20	0
22	0
24	0
26	0
28	0
30	0
32	0
34	0
36	0
38	10
40	55
42	96
44	36
46	27
48	2
50	1
>50	0



Andrew K. Kercher — Operator

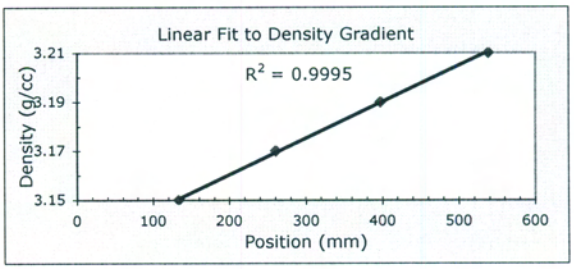
February 7, 2007 — Date

Data Report Form DRF-02: Measurement of SiC Density using a Density Gradient Column

Procedure:	AGR-CHAR-DAM-02 Rev. 3
Operator:	Dixie Barker
Filename:	\\mc-agr\AGR\DensityColumn\D07020801_DRF02R3.xls
Sample ID:	LEU03-09T-E01
Sample description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Float expiration date:	07/2007
Gauge expiration date:	11/2007
Bath temperature:	23.1 °C

Calibrated Floats			
Density	Top of Float	Bottom of Float	Center of Mass
3.150	120.53	139.55	133.21
3.170	244.99	269.35	261.23
3.190	382.71	405.37	397.82
3.210	522.90	546.58	538.69

Linear Fit			
slope	StDev	intercept	StDev
1.48E-04	2.56E-06	3.13E+00	8.52E-04



Sample Density								
Fragment Number	Fragment Position	Calculated Density	Fragment Number	Fragment Position	Calculated Density	Fragment Number	Fragment Position	Calculated Density
1	420.72	3.1930	26	487.72	3.2029	51		
2	456.02	3.1982	27	488.32	3.2030	52		
3	457.66	3.1985	28	485.01	3.2025	53		
4	458.83	3.1986	29	489.85	3.2032	54		
5	466.21	3.1997	30	489.85	3.2032	55		
6	468.36	3.2000	31	490.51	3.2033	56		
7	468.70	3.2001	32	490.51	3.2033	57		
8	474.99	3.2010	33	491.51	3.2035	58		
9	475.89	3.2012	34	492.08	3.2035	59		
10	476.27	3.2012	35	492.72	3.2036	60		
11	476.76	3.2013	36	493.70	3.2038	61		
12	478.07	3.2015	37	494.81	3.2039	62		
13	479.82	3.2017	38	496.65	3.2042	63		
14	479.82	3.2017	39	497.20	3.2043	64		
15	479.82	3.2017	40	497.55	3.2044	65		
16	480.00	3.2018	41	497.55	3.2044	66		
17	481.44	3.2020	42	497.72	3.2044	67		
18	481.44	3.2020	43	500.38	3.2048	68		
19	483.02	3.2022	44	500.38	3.2048	69		
20	484.14	3.2024	45	503.65	3.2053	70		
21	484.81	3.2025	46	503.65	3.2053	71		
22	485.94	3.2026	47	507.43	3.2058	72		
23	486.43	3.2027	48	508.97	3.2060	73		
24	486.43	3.2027	49	509.74	3.2062	74		
25	486.43	3.2027	50	509.02	3.2060	75		

Average density of SiC fragments:	3.2026
Standard deviation in density of SiC fragments:	0.0024
Uncertainty in calculated density of SiC fragments:	0.0016

Dixie Barker
Operator

2-8-07
Date

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, Jr.
Mount ID:	M07011801L
Sample ID:	LEU03-09T-B01
Sample Description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Folder containing data:	\\mc-agr\AGR\2-MGEM\R07020501\

Particle #	Grid Position	Diattenuation			Equivalent BAFo		
		Average	St. Dev.	Ave. Error	Average	St. Dev.	Ave. Error
1	4,4	0.0095	0.0029	0.0005	1.0285	0.0087	0.0015
2	4,5	0.0094	0.0052	0.0006	1.0282	0.0156	0.0018
3	4,6	0.0081	0.0024	0.0005	1.0243	0.0072	0.0015
4	5,4	0.0087	0.0030	0.0005	1.0261	0.0090	0.0015
5	5,5	0.0090	0.0029	0.0005	1.0270	0.0087	0.0015
6	5,6	0.0078	0.0029	0.0005	1.0234	0.0087	0.0015
7	6,4	0.0092	0.0033	0.0006	1.0276	0.0099	0.0018
8	6,5	0.0083	0.0028	0.0006	1.0249	0.0084	0.0018
9	6,6	0.0091	0.0028	0.0006	1.0273	0.0084	0.0018
10	6,7	0.0098	0.0029	0.0005	1.0294	0.0087	0.0015
Average		0.0089	0.0031	0.0005	1.0267	0.0093	0.0016

Mean of average BAFo per particle:	1.0267
Standard deviation of average BAFo per particle:	0.0020

Comments

G. E. Jellison — Operator

Feb 7 2007 — 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, Jr.
Mount ID:	M07011801L
Sample ID:	LEU03-09T-B01
Sample Description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Folder containing data:	\\mc-agr\AGR\2-MGEM\R07020501\

Particle #	Grid Position	Diattenuation			Equivalent BAFo		
		Average	St. Dev.	Ave. Error	Average	St. Dev.	Ave. Error
1	4,4	0.0083	0.0037	0.0006	1.0249	0.0111	0.0018
2	4,5	0.0069	0.0033	0.0007	1.0207	0.0099	0.0021
3	4,6	0.0069	0.0029	0.0007	1.0207	0.0087	0.0021
4	5,4	0.0065	0.0034	0.0006	1.0195	0.0102	0.0018
5	5,5	0.0066	0.0031	0.0007	1.0198	0.0093	0.0021
6	5,6	0.0067	0.0031	0.0006	1.0201	0.0093	0.0018
7	6,4	0.0068	0.0033	0.0007	1.0204	0.0099	0.0021
8	6,5	0.0069	0.0030	0.0010	1.0207	0.0090	0.0030
9	6,6	0.0075	0.0029	0.0007	1.0225	0.0087	0.0021
10	6,7	0.0061	0.0028	0.0007	1.0183	0.0084	0.0021
Average		0.0069	0.0032	0.0007	1.0208	0.0095	0.0021

Mean of average BAFo per particle:	1.0208
Standard deviation of average BAFo per particle:	0.0018

Comments

G. E. Jellison — Operator

Feb. 7, 2007 — Date

Data Report Form DRF-20: Counting of Particles with SiC Gold Spot Defects by Visual Inspection

Procedure:	AGR-CHAR-DAM-20 Rev. 1
Operator:	John Hunn
Sample ID:	LEU03-09T-D02
Sample Description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Filename:	\\mc-agr\AGR\GoldSpots\G07011101_DRF20R1.xls

Mean average weight/particle (g):	7.74E-04
Uncertainty in average weight/particle (g):	1.03E-06
Weight of sample of particles (g):	9.418
Approximate number of particles in sample:	12168
Uncertainty in number of particles in sample:	16

Number of particles with gold spot defects:	11

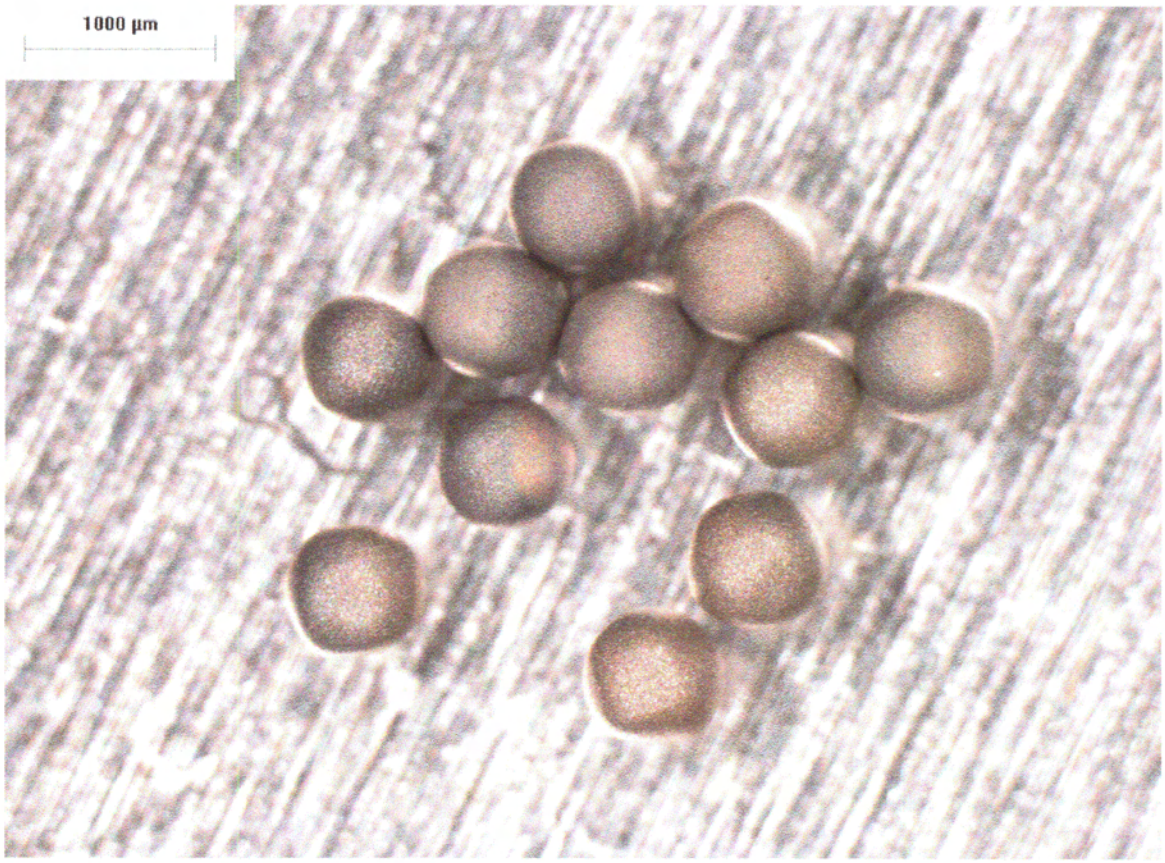
Comments on unusual visual characteristics of SiC

Image P0701110201 shows particles with goldspots.

John Hunn — Operator

1-11-07 — Date

11 particles with possible gold spots found out of 12168 particles analyzed.



Data Report Form DRF-20: Counting of Particles with SiC Gold Spot Defects by Visual Inspection

Procedure:	AGR-CHAR-DAM-20 Rev. 1
Operator:	John Hunn
Sample ID:	LEU03-09T-D03
Sample Description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Filename:	\\mc-agr\AGR\GoldSpots\G07011801_DRF20R1.xls

Mean average weight/particle (g):	7.74E-04
Uncertainty in average weight/particle (g):	1.03E-06
Weight of sample of particles (g):	7.949
Approximate number of particles in sample:	10271
Uncertainty in number of particles in sample:	14

Number of particles with gold spot defects:	6

Comments on unusual visual characteristics of SiC

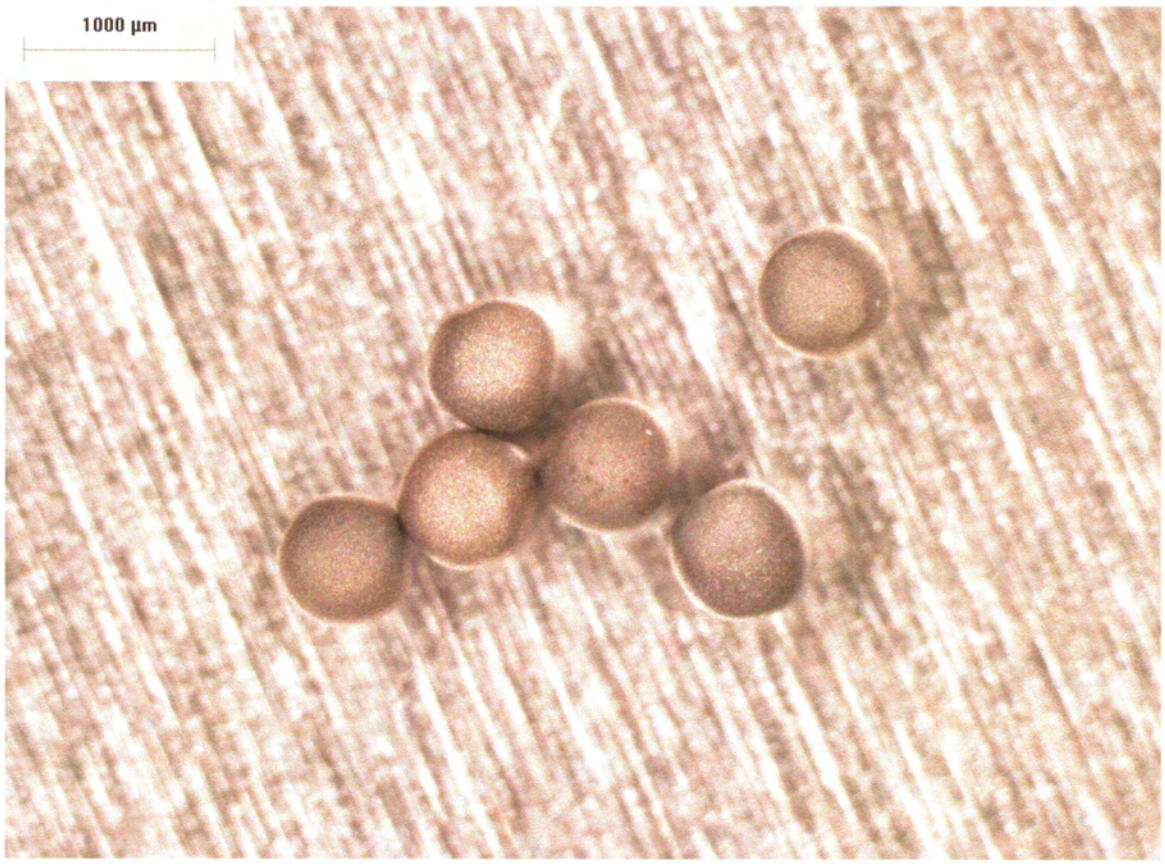
Image P0701180101 shows particles with goldspots.

John Hunn
Operator

1-18-07
Date

LEU03-09T-D03

6 particles with possible gold spots found out of 10271 particles analyzed.



Data Report Form DRF-20: Counting of Particles with SiC Gold Spot Defects by Visual Inspection

Procedure:	AGR-CHAR-DAM-20 Rev. 1
Operator:	John Hunn
Sample ID:	LEU03-09T-D01
Sample Description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Filename:	\\mc-agr\AGR\GoldSpots\G07011802_DRF20R1.xls

Mean average weight/particle (g):	7.74E-04
Uncertainty in average weight/particle (g):	1.03E-06
Weight of sample of particles (g):	6.702
Approximate number of particles in sample:	8659
Uncertainty in number of particles in sample:	12

Number of particles with gold spot defects:	5

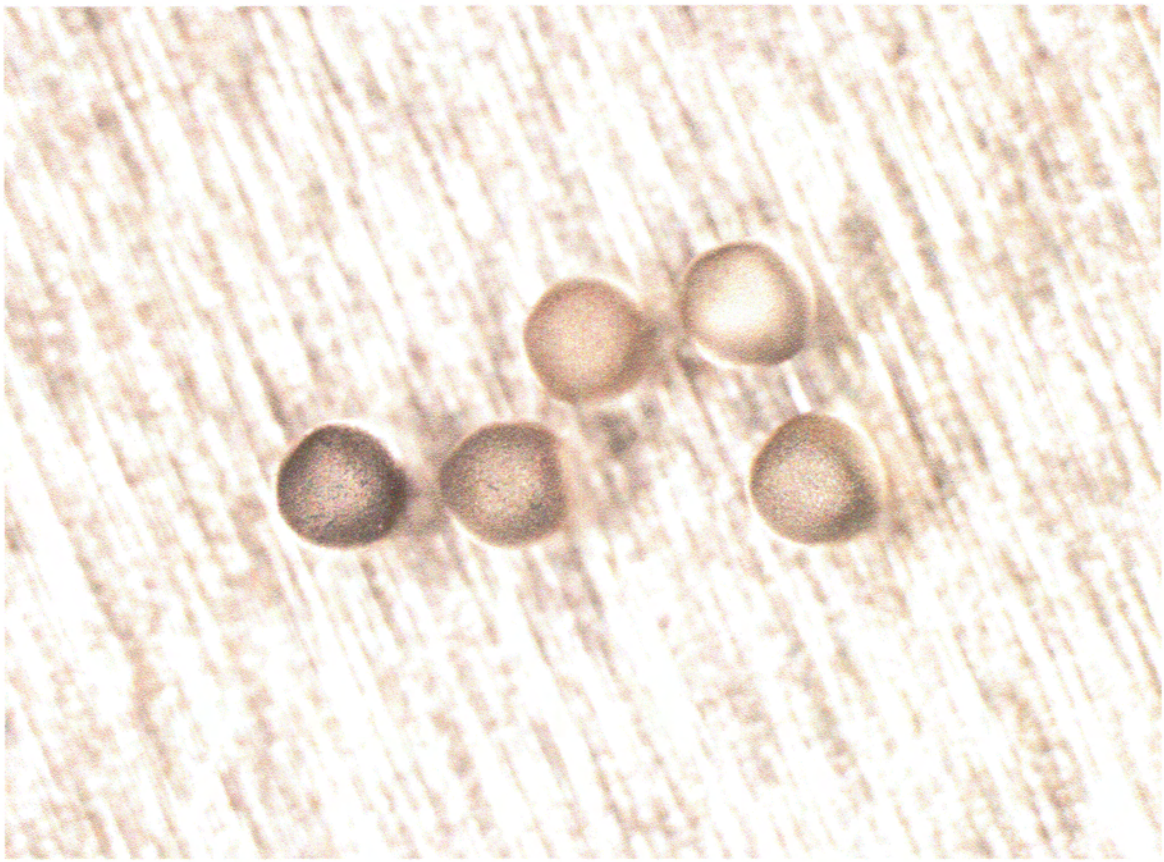
Comments on unusual visual characteristics of SiC

Image P0701180102 shows particles with goldspots.

John Hunn — Operator

1-18-07 — Date

5 particles with possible gold spots found out of 8659 particles analyzed.



Data Report Form DRF-20: Counting of Particles with SiC Gold Spot Defects by Visual Inspection

Procedure:	AGR-CHAR-DAM-20 Rev. 1
Operator:	John Hunn
Sample ID:	LEU03-09T-D04
Sample Description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Filename:	\\mc-agr\AGR\GoldSpots\G07012301_DRF20R1.xls

Mean average weight/particle (g):	7.74E-04
Uncertainty in average weight/particle (g):	1.03E-06
Weight of sample of particles (g):	9.243
Approximate number of particles in sample:	11942
Uncertainty in number of particles in sample:	16

Number of particles with gold spot defects:	10

Comments on unusual visual characteristics of SiC

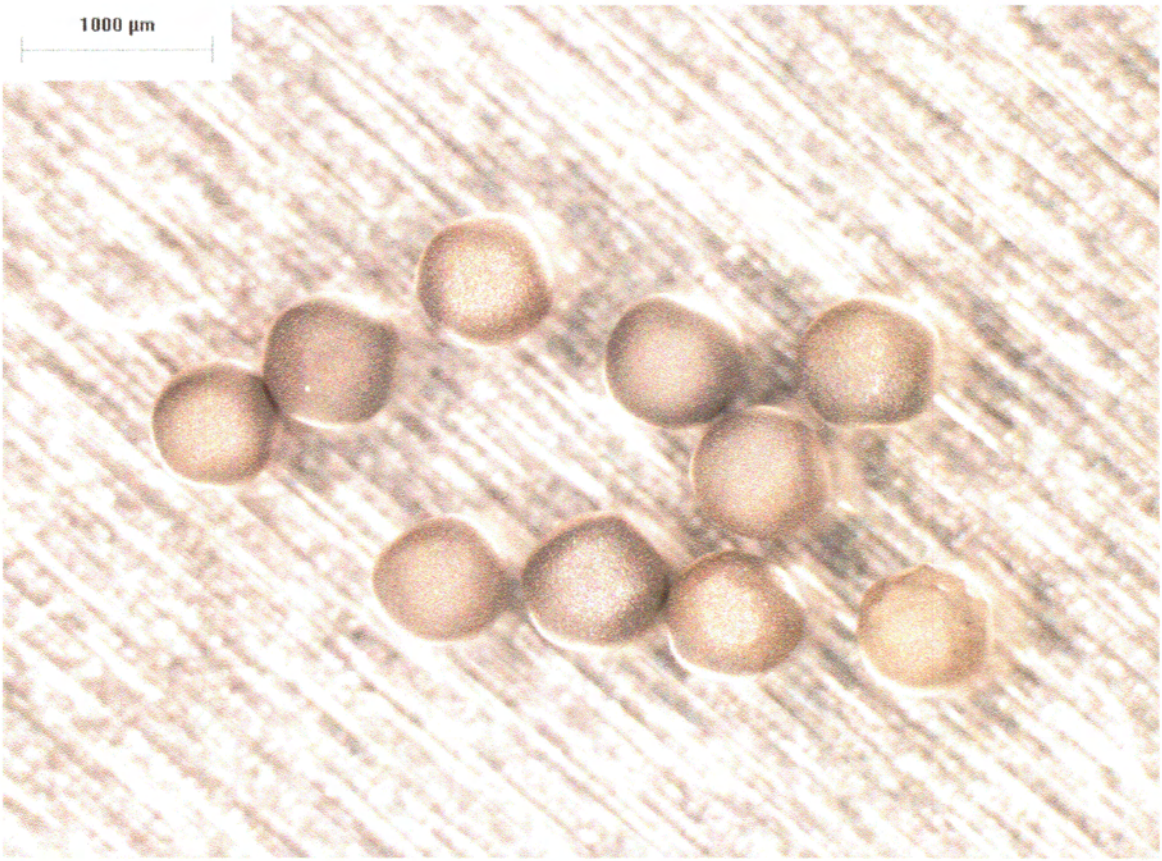
Image P0701230101 shows particles with goldspots.

John Hunn — Operator

1-23-07 — Date

LEU03-09T-D04

10 particles with possible gold spots found out of 11942 particles analyzed.



Data Report Form DRF-07: Imaging of Particle Diameter and Aspect Ratio Using an Optical Microscope System

Procedure:	AGR-CHAR-DAM-07 Rev. 1
Operator:	Andrew K. Kercher
Sample ID:	LEU03-09T-C01
Sample Description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\P06121901

DMR Calibration Expiration Date:	9/18/07
Stage Micrometer Calibration Expiration Date:	2/17/07
Measured Value for 1200 µm in Stage Micrometer Image:	1200. µm

Andrew K. Kercher — Operator

December 19, 2006 — Date

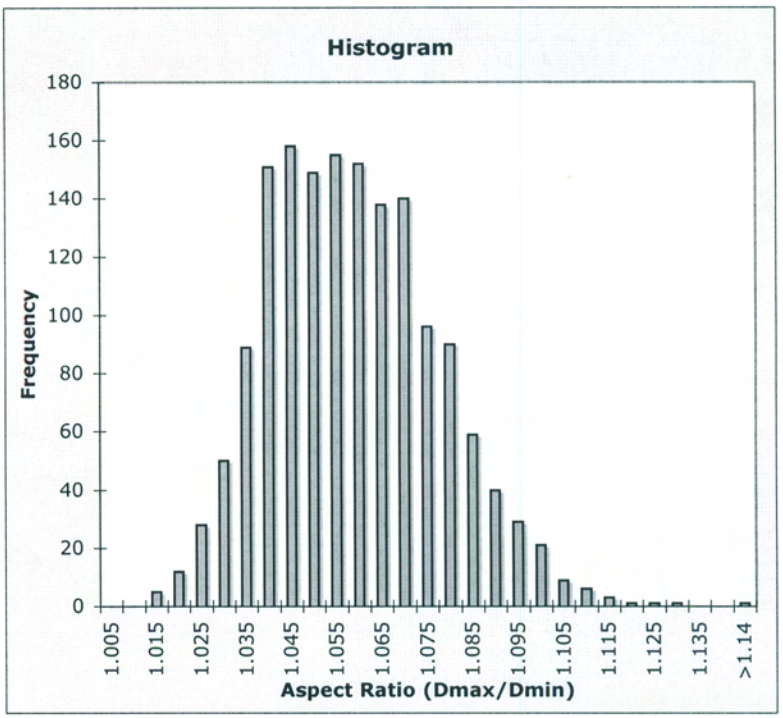
Data Report Form DRF-10B: Measurement of Particle Aspect Ratio (Dmax/Dmin)

Procedure:	AGR-CHAR-DAM-10 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P06121901\
Sample ID:	LEU03-09T-C01
Sample Description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P06121901_output\

Number of particles analyzed:	1584
Number of particles with aspect ratio > 1.14	1
Average particle aspect ratio:	1.056

Distribution of the aspect ratio (top binned)

Aspect Ratio (D)	*Frequency*
1.005	0
1.010	0
1.015	5
1.020	12
1.025	28
1.030	50
1.035	89
1.040	151
1.045	158
1.050	149
1.055	155
1.060	152
1.065	138
1.070	140
1.075	96
1.080	90
1.085	59
1.090	40
1.095	29
1.100	21
1.105	9
1.110	6
1.115	3
1.120	1
1.125	1
1.130	1
1.135	0
1.140	0
>1.14	1



Andrew K. Kercher — Operator

December 21, 2006 — Date

Data Report Form DRF-19: Counting of Particles with Missing OPyC Layer by Visual Inspection

Procedure:	AGR-CHAR-DAM-19 Rev. 1
Operator:	John Hunn
Sample ID:	LEU03-09T-D01
Sample Description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Filename:	\\mc-agr\AGR\MissingOPyC\X07010401_DRF19R1.xls

Mean average weight/particle (g):	7.74E-04
Uncertainty in average weight/particle (g):	1.03E-06
Weight of sample of particles (g):	24.075
Approximate number of particles in sample:	31089
Uncertainty in number of particles in sample:	41

Number of particles with missing OPyC layer:	0

Comments on unusual visual characteristics of OPyC

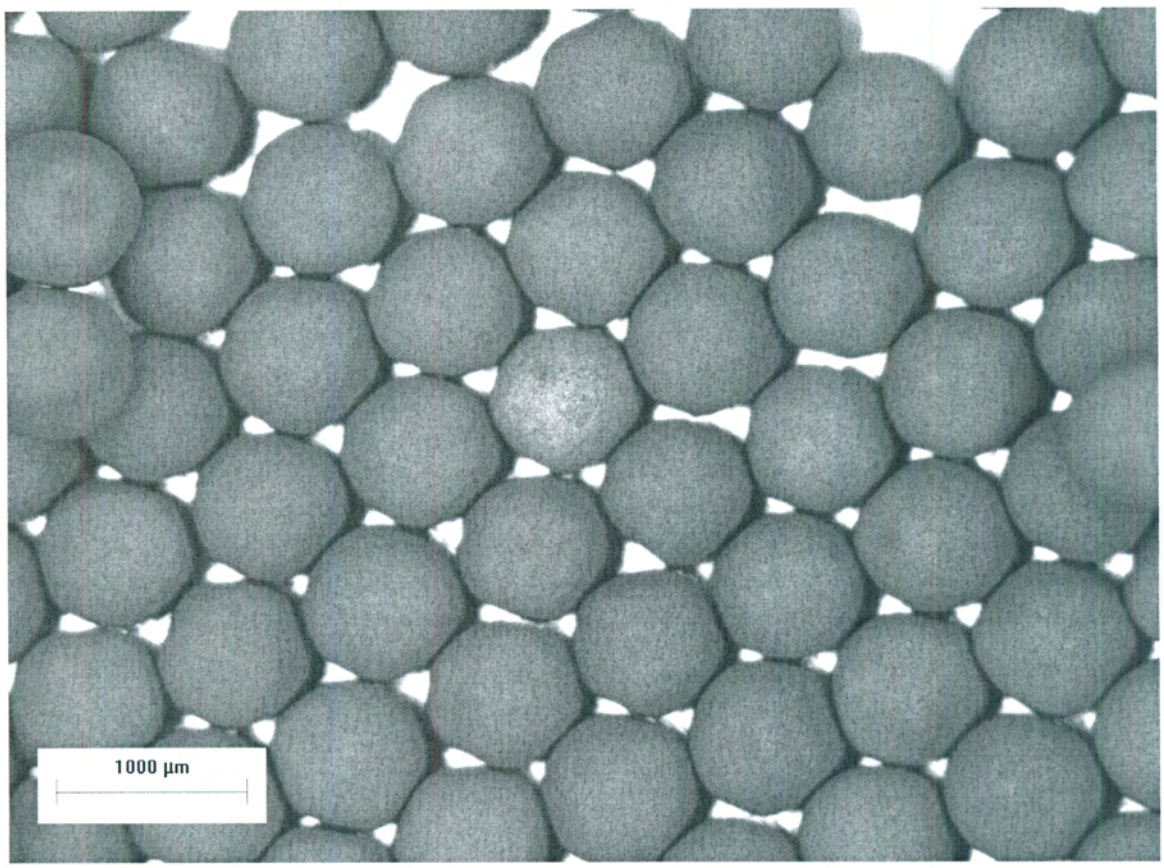
Observed 3 particle with mottled surface (image P0701040101.tif). Broke these particles to look at layers. The OPyC layers appeared to be of normal thickness. This anomaly was also observed on AGR-1 variant 1 particles and is reported in data compilation ORNL/TM-2006/020.

John Hunn — Operator

1-4-07 — Date

LEU03-09T-D01

Particle with unusual mottled gray OPyC surface appearance is shown in the image below. 3 out of 31089 particles were observed with this appearance. This anomaly does not appear to be associated with thin or missing OPyC. Also seen in upper left corner is a dark blemish, which is often observed on surface of OPyC and appears to be caused by temporary particle to particle contact during coating. Both of these anomalies of the OPyC surface appearance have been observed on AGR-1 particles and are discussed in data compiations ORNL/TM-2006/019 and ORNL/TM-2006/020.



Data Report Form DRF-23: Imaging of SiC Grain Structure

Procedure:	AGR-CHAR-DAM-23 Rev. 0
Operator:	Paul Menchhofer
Filename:	\\mc-agr\AGR\SEM\E07012901_DRF23R0.xls
Sample ID:	LEU03-09T-B01
Sample Description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Mount Number(s):	M07011901L
Folder name containing images:	\\mc-agr\AGR\SEM\

Images of SiC grain structure			
	particle 1	particle 2	particle 3
1000x image filename	63222	63224	63226
2500x image filename	63223	63225	63227
grain structure acceptable	yes	yes	yes

Comments

P. A. Menchhofer — Operator

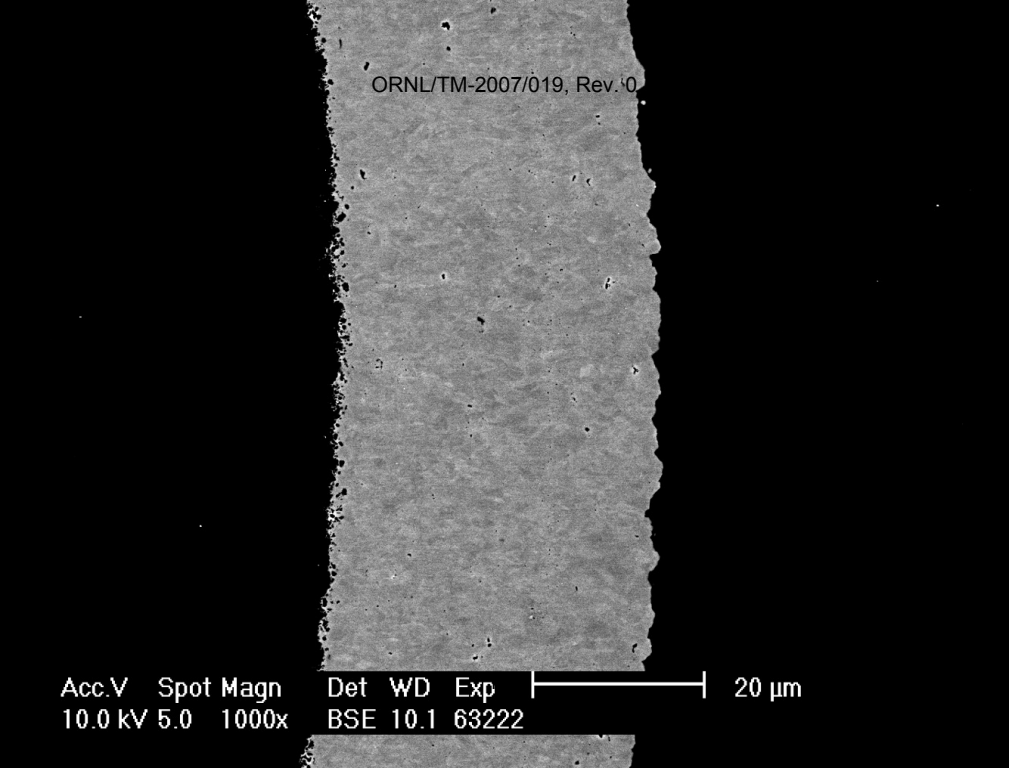
1.31.07 — Date

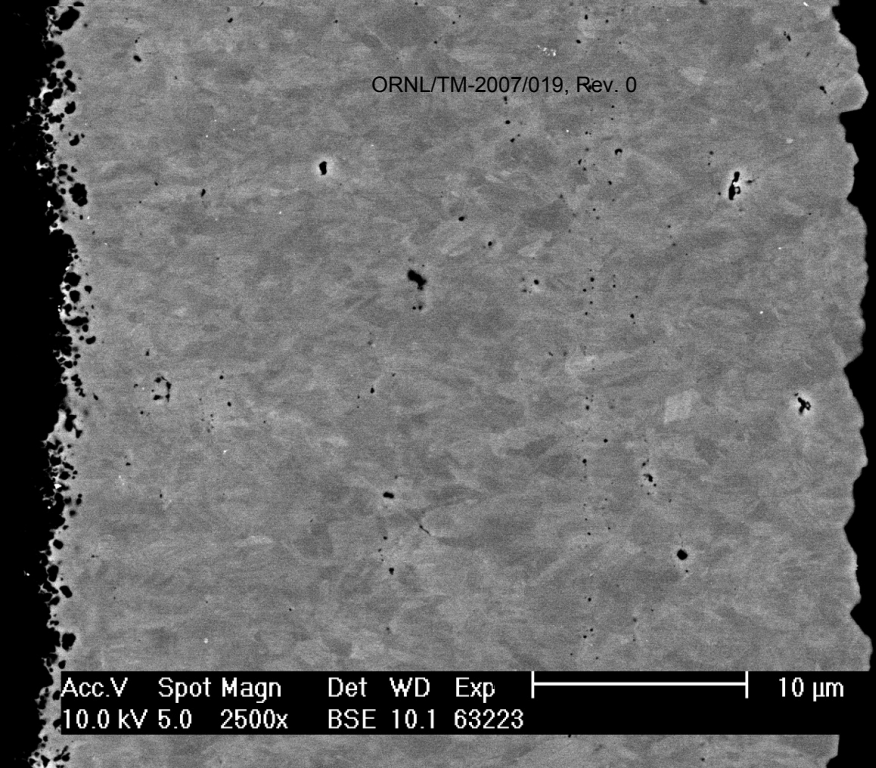
John Johnson — QC Supervisor

1-31-07 — Date

M K Lee — QA Reviewer

2/1/07 — Date


Acc.V Spot Magn Det WD Exp
10.0 kV 5.0 1000x BSE 10.1 63222
20 µm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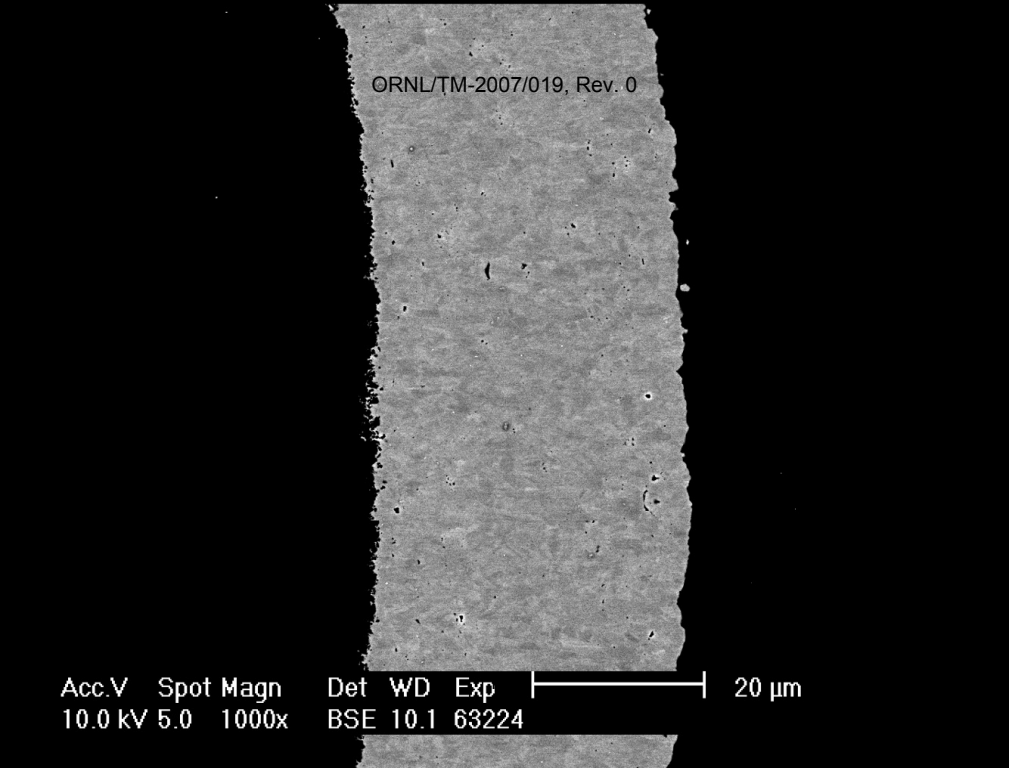
10 µm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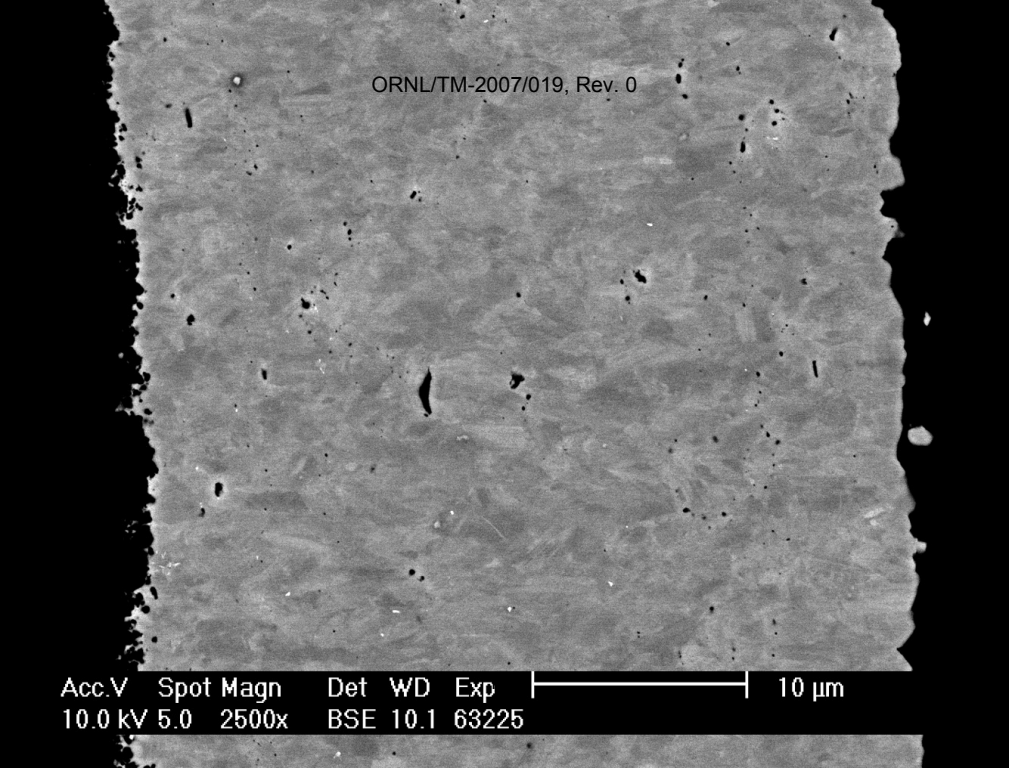
20 µm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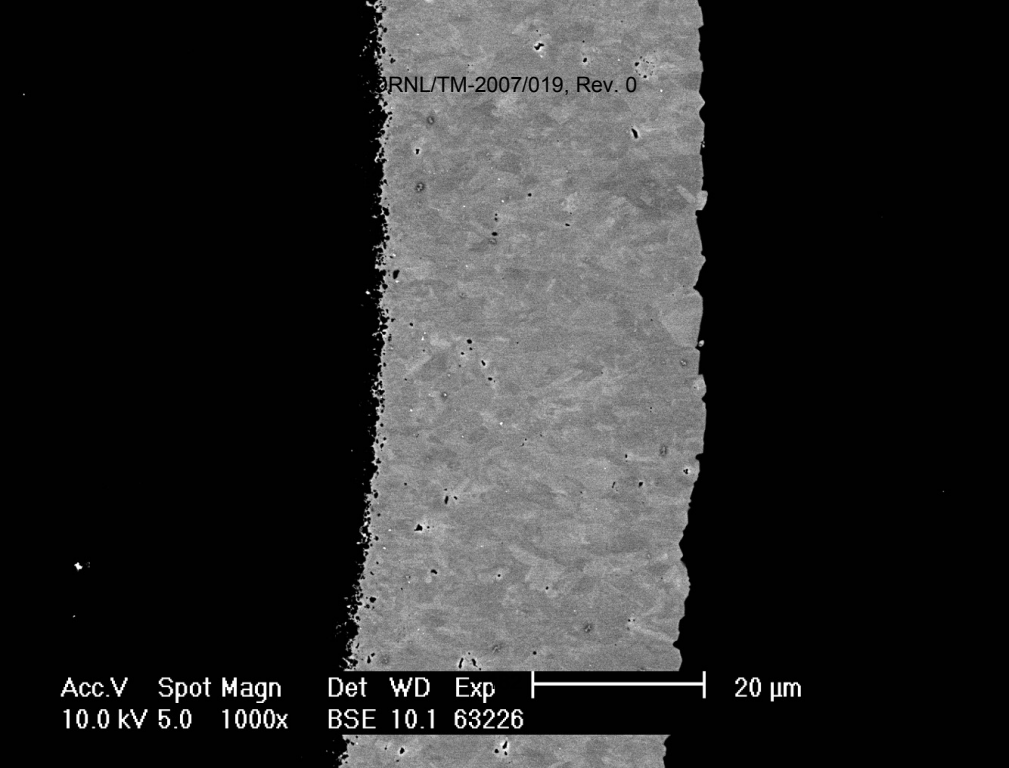
10 µm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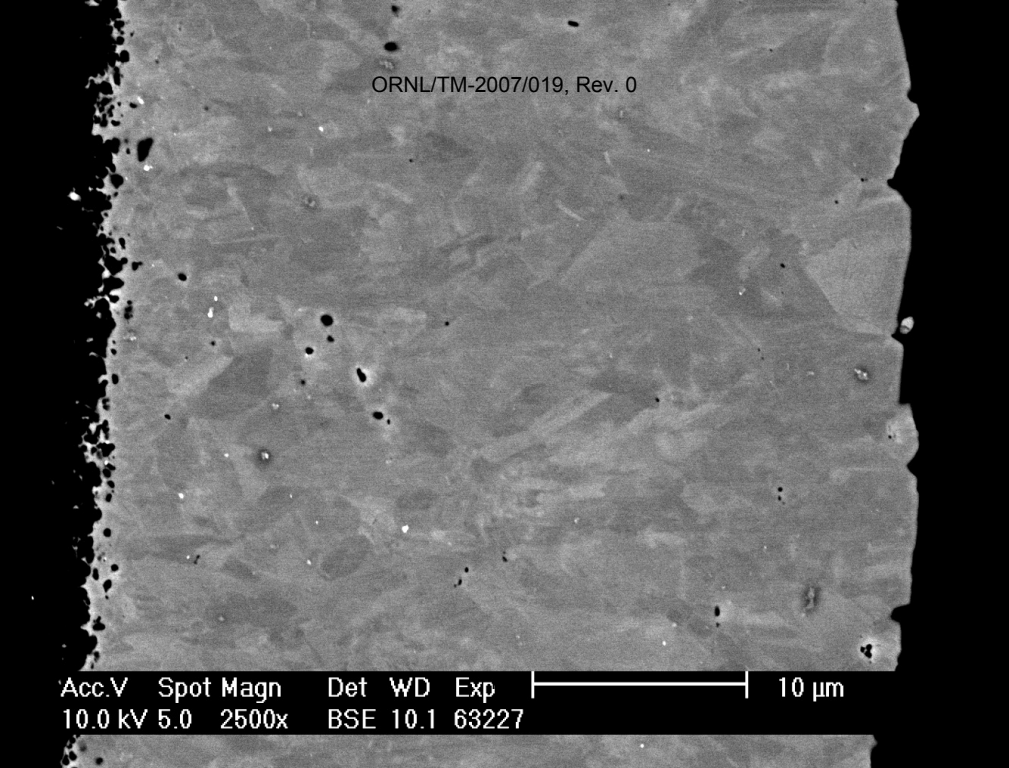
20 µm


Acc.V Spot Magn Det WD Exp
10.0 kV 5.0 2500x BSE 10.1 63227
10 µm

For Information Only

The information in the remainder of this section reports results of measurements not required by the fuel specification and is provided for information only.

Data Report Form DRF-22: Estimation of Average Particle Weight

Procedure:	AGR-CHAR-DAM-22 Rev. 1
Operator:	Dixie Barker
Particle Lot ID:	LEU03-09T-H01
Particle Lot Description:	AGR-3/4 driver TRISO composite on kernel comp 69303
Filename:	\\mc-agr\AGR\ParticleWeight\W06121901_DRF22R1.xls

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Weight of particles (g):	1.37E-01	1.45E-01	1.32E-01	1.07E-01	1.20E-01
Number of particles:	177	187	171	138	155
Average weight/particle (g):	7.75E-04	7.74E-04	7.73E-04	7.78E-04	7.73E-04

Mean average weight/particle (g):	7.744E-04
Standard error in mean average weight/particle (g):	1.03E-06

Dixie Barker
Operator

12-19-06
Date

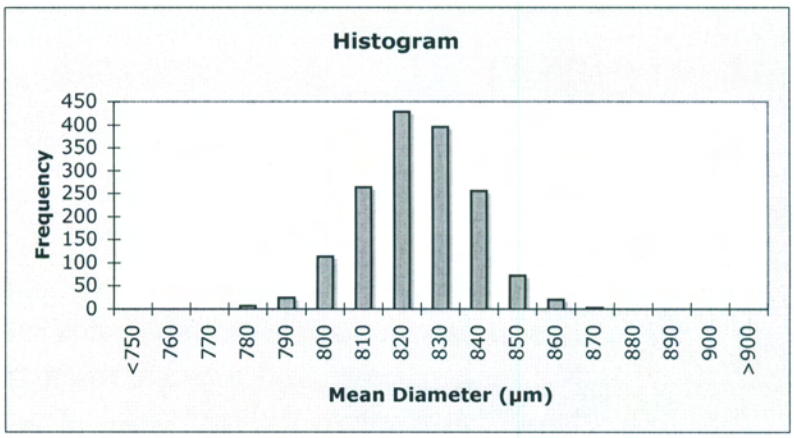
Data Report Form DRF-10A: Measurement of Particle Diameter

Procedure:	AGR-CHAR-DAM-10 Rev. 2
Operator:	Andrew K. Kercher
Folder name containing images:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P06121901\
Sample ID:	LEU03-09T-C01
Sample Description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Folder name containing processed data:	\\mc-agr\AGR\ImageProcessing\Completed_Shadow\P06121901_output\

Number of particles analyzed:	1584
Mean of the average diameter of each particle (μm):	818.9
Standard deviation in the average diameter of each particle (μm):	14.2

Distribution of the average particle diameter (top binned)

Mean Diameter (μm)	*Frequency*
<750	0
760	0
770	0
780	7
790	25
800	114
810	264
820	428
830	395
840	256
850	72
860	20
870	3
880	0
890	0
900	0
>900	0



Operator

December 21, 2006
Date

Data Report Form DRF-31: Measurement of Open Porosity using a Mercury Porosimeter

Procedure:	AGR-CHAR-DAM-31 Rev. 1
Operator:	S. D. Nunn
Coated particle batch ID:	LEU03-09T-I01
Batch Description:	AGR-3/4 driver TRISO composite on BWXT kernel composite 69303
Thermocouple Expiration Date:	5/19/07
Penetrometer Expiration Date:	5/25/07
Completed DRF Filename:	\\mc-agr\AGR\Porosimeter\S07011901\S07011901_DRF31R1.xls

Mean average weight/particle (g):	7.74E-04
Standard error in mean average weight/particle (g):	1.03E-06

Weight of particles (g):	3.6122
Approximate number of particles:	4667
Uncertainty in number of particles:	6
Total envelope volume of sample (cc):	1.327
Average envelope volume/particle (cc):	2.84E-04
Sample envelope density (g/cc):	2.723

Average particle diameter (microns):	8.16E+02
Average surface area/particle (cm2):	2.09E-02
Total sample surface area (cm2):	9.76E+01
Intruded mercury volume from 250-10,000 psia (cc):	1.14E-02
Open porosity (ml/m2):	1.17E+00

Comments

S. D. Nunn
Operator

1/19/07
Date