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WANL-TME-1869

October 22, 1968

Westinghouse Astronuclear Laboratory

PEWEE I FABRICATION REPORT

(Title Unclassified)

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Westinghouse Nuclear Laboratory

PEWEE I FABRICATION REPORT

(Title Unclassified)

Classification cancelled (or changed to) _____
by authority of DOE
by H.F.C. TIC, date SEP 10 1973

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Prepared by:

WNCO Staff

Approved by:

G.R. Kilp

G.R. Kilp, Manager
NERVA Fuel Engineering, WNCO

SPECIAL REVIEW DETERMINATION	Reviewers	Class.	Date
	KAW	u	4-8-82
Class: <u>u</u>			

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ABSTRACT

(U) This report presents the fabrication history of the uranium-loaded graphite fuel elements for the PEWEE I reactor by Westinghouse Astronuclear Core Operations (WNCO) at Cheswick, Pennsylvania, during the period from December 1967 through April 1968.

(U) It is the purpose of the report to summarize the production history of the fueled elements and reactor support hardware for the PEWEE I core, with particular emphasis being placed on the development and implementation of new or revised processing techniques and production schedule records.

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1.0 INTRODUCTION (U)

(U) Fuel element production for the PEWEE I core included a number of successful manufacturing modifications.

(CRD) These included (1) the use of a 75% NbC/25% composite tip, (2) a high hydrogen/salt ratio chemistry for the standard high temperature NbC process (GED), (3) a new low temperature NbC coating using a methane gas stream additive as the source of carbon, and (4) fixture modifications to coat a new system of support hardware.

(U) These modifications are reflected in the raw materials and processing procedures used for PEWEE I manufacturing. Tables 1 and 2 are lists of raw materials and WNCO process specifications, respectively.

(U) The remainder of the report is a presentation of the WNCO production effort for the PEWEE I reactor.

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2.0 PROGRAM REQUIREMENTS (U)

2.1 FUEL ELEMENT SCHEDULES (U)

(CRD) The PEWEE I production began with fueled extrusions during the week ending December 7, 1967. Processing of elements through subsequent steps of manufacture included coordination of the combined efforts of WNCO, Y-12, and WEFF to accomplish the desired matrix and coating variables, including additive and impregnated elements coated by GEM and GED processes. Schedules of extrusion through final inspection, certification, and delivery were maintained throughout the period. GED coating at WNCO began on February 13, 1968 and was completed on March 14, 1968. GEM coating at WEFF began on February 27, 1968 and was completed on March 26, 1968. "X" coating of GED-coated elements began on March 8, 1968 at WNCO and was completed on March 29, 1968. Final inspection and final shipment of all fuel elements from WNCO were completed on schedule on April 15, 1968.

2.2 FUEL ELEMENTS (U)

(U) Ordering of fuel elements from WNCO for PEWEE I was accomplished by work orders prepared by WANL Production Control. Table 3 is a summary of this effort. This tabulation indicates the type of element, pertinent WANL drawing, processing suppliers, order number and quantities, number of applicable change notices against original order, and some description of the element matrix, coating, and physical geometry.

(CRD) The basic work order included a matrix exchange of elements with additive elements received from Y-12 in the "as-graphitized" condition and impregnated elements shipped to Y-12 in the "as-leached, re-graphitized" condition. The supplier for finished elements was designated by "Manufacturer through Graphitize - Manufacturer after graphitize," i.e., W-W_g, Y-W.*

* W - Westinghouse Astronuclear Laboratory

Y - Y-12 Plant, Oak Ridge National Laboratory

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(U) Table 4 summarizes the weekly progress from extrusion through shipment of core candidate elements and required samples. Table 5 summarizes overall process yields by process stage for core candidate elements. All elements produced at WNCO were delivered. In addition to core candidates, elements were shipped for required test samples, component tests, or other evaluations (see Table 6).

(CRD) WNCO delivered to LASL 157 core, spare, and sample fuel elements, which was 59 elements over the required quantity.

(U) WNCO delivered to WANL 63 sample and corrosion test elements for qualification of core candidates shipped to LASL

(U) WNCO delivered 40 core candidate elements to Y-12 in the as-impregnated condition and received 155 elements in the as-graphitized condition as a matrix exchange for further processing.

(U) WNCO delivered 220 elements to WANL for component testing and other evaluation. Table 6 lists the requisitioning section, type of evaluation, quantity desired, and quantity delivered.

(U) Table 7 lists the axial support hardware ordering information. This table lists type, style, pertinent WANL drawing, order number, number of applicable change notices against original order, quantities processed, quantities shipped for final evaluation at WANL, and yield ratios of quantities processed related to quantity shipped.

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3.0 FABRICATION HISTORY OF FUELED ELEMENTS (U)

3.1 MATERIALS AND EXTRUSION BATCH FORMULATION (U)

(CRD) PEWEE I fueled elements were fabricated with 85 parts of cross-blended graphite flour to 15 parts of carbon black, General Atomic fuel beads, and 27 percent "varcum" catalyzed with maleic anhydride.

(CRD) Aim fuel loadings of graphitized elements were calculated by the carbon/uranium balance procedures utilized previously. The relationship between aim loading and desired final loading for materials utilized was as follows:

$$\text{Aim Loading (mg/cc)} = \text{Final Loading (gms/inch)} \times 192.93$$

(CRD) The only uranium loading value produced at WNCO was 525 mg/cc (final).

(U) A tabulated summary of PEWEE I permeability data for elements extruded at Y-12 and machined at WNCO as well as those fabricated entirely at WNCO is presented in Table 8.

3.2 EXTRUSION (U)

(CRD) The extrusion run was normal and in accord with previous experience at a pressure of 95 ± 10 tons and a rate of 100 ± 10 in./min. Variations in these parameters and an extrusion summary are given in Table 9.

(U) Twenty-four hour engineering coverage was provided during the extrusion of PEWEE I fuel elements.

3.3 CURING, BAKING, AND GRAPHITIZING (U)

(CRD) Cure, bake, and graphitization procedures for PEWEE I elements were identical to NRX-A6 and XE-2 procedures.

3.4 TIP BRAZING (CRD)

(CRD) Fabrication of the PEWEE I elements utilized a "transition tip" consisting of an unfueled transition piece brazed to a 75% NbC/25% C hot end wafer. The "transition tip" was provided to WNCO as a unit. WNCO then brazed this unit onto the hot end of the

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element. The brazing operation was the same as that for XE-2 production, using -325 mesh molybdenum powder.

(CRD) The tip-to-element joint was induction-heated to a surface temperature of 2425°C, held for 10 seconds, and allowed to cool. A 1500 psi compressive load was maintained throughout the thermal cycle.

3.5 MACHINING (U)

(CRD) The PEWEE I elements were machined according to the same manufacturing procedures used for NRX-A6 and XE-2 fuel elements. A total of 470 carbide-tipped elements, plus 80 non-fuel elements, were milled to drawing requirements for across-flats dimensions without any serious degradation in the diamond cutting tools. This performance matched the best of any previous diamond milling for high loaded graphite-tipped elements.

(CRD) The reaming of carbide versus graphite-tipped elements was similar in regard to tool wear. However, twice as much tooling wear was noticed for reaming the 2-1/2 percent additive elements.

3.6 LEACHING (U)

(CRD) The PEWEE I fuel elements were leached with the same process used for NRX-A6 and XE-2.

3.7 NIOBIUM CARBIDE COATING (U)

(CRD) A series of development runs was made in preparation for PEWEE I production, utilizing both the "NRX-A6" and "high hydrogen" chemistries. The "high hydrogen" process utilized a 2.25/1 hydrogen to salt ratio compared to the conventional 1/1 ratio. This enabled the coating time for equivalent thicknesses to be reduced from 24 hours to 14 hours. An evaluation of the corrosion behavior of elements receiving both types of coating failed to isolate any marked differences between the two. Consequently, the high hydrogen process was selected for its greater productivity potential.

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(CRD) Aim coating thicknesses for PEWEE I were 1.2 mils at the midband and 2.8 mils at the hot end. Temperatures required to achieve this profile were 1370°C, 1530°C, and 1780°C for the cold end, middle, and hot end of the elements, respectively. Improved temperature control was obtained by establishing voltage tables for each zone on the furnace coil and applying predetermined logic to make adjustments. This prevented the technician from making arbitrary power adjustments and succeeded in decreasing the range of temperatures on a given sight port to $\pm 5^{\circ}\text{C}$.

(CRD) Even with good temperature control, some problems with weight gain and thickness profile were encountered. The average coating run weight gain ranged from 63.0 grams to 78.0 grams. The mid-band thickness ranged from 0.9 mils to 1.5 mils. The hot end thickness ranged from 2.4 mils to 3.0 mils. This control spread may be due to difficulties encountered with the generation of constant salt delivery rate from saturators. The newly installed salt loss control systems should improve this situation considerably.

(CRD) Both the "A6" chemistry and "high hydrogen" chemistry processes are identified as "GED" processes (G end diffusion). The WEFF facility, meanwhile, developed the GEM (G end methane) process for use in PEWEE I. This latter process is operative at low temperatures (approximately 1050°C), and the carbon is supplied from the methane content in the gas stream rather than the element. Weight gain and profile problems were evident in these runs.

(CRD) In addition, coarse crystals were deposited at the inlet end of the channels and the coated across-flats dimension at the hot end exceeded drawing limits. The across-flats dimensional control of GEM-coated elements is more difficult than for GED coatings because the coating buildup is 100 percent of the total coating thickness and because there is no self-limiting effect due to diffusion of carbon.

3.8 MOLYBDENUM COATING (CRD)

(CRD) The molybdenum overcoating process was modified (increased total gas flow 24 percent) to maintain the same coating gas velocity for the high-void PEWEE I elements as was utilized for the NRX-A6 and XE-2 low-void elements.

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(CRD) Coating profiles, as determined with resistance measurements, were similar to previous core production profiles; weight gains were equivalent when the bore size differences were taken into account. Table 10 is the production summary including weight deposition and retention values. It should be noted that the standard matrices (G05K) retained less molybdenum than the additive elements (G07K), which in turn, retained less than the impregnated (G06K) elements. No gross abnormalities or problems were experienced throughout the production campaign.

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4.0 NbC COATING OF SUPPORT HARDWARE (U)

4.1 PEDESTAL, OUTER CUP, AND TAPERED WASHER (U)

(CRD) The substrate for PEWEE I pedestals, outer cups, and tapered washers was a 75 v/o NbC/25 v/o graphite composite. The components were coated with 0.5 to 2.0 mils of NbC deposited at 1900°C during a 4-hour period.

4.2 INNER CUPS (U)

(CRD) The pyrolytic cups were coated with 0.7 to 1.7 mils of NbC deposited at 1960°C during a 3-hour period.

4.3 OUTER SLEEVE (U)

(CRD) The graphite sleeves were coated with 2.0 to 3.5 mils of NbC deposited at 1940°C during a 6-hour period. This coating was performed in two steps to allow rotation of the component on the fixturing to eliminate coating defects.

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TABLE 1 (CRD)

PEWEE I RAW MATERIALS (U)

Material	Specification	Supplier
Special Uranium Particles	PDS 30050-C	General Atomics
Graphite Flour	PDS 30046-B	Great Lakes Carbon Company
Carbon Black	PDS 30047-B	R. T. Vanderbilt Company, Inc.
Furfuryl Alcohol	PDS 30048-B	Varcum Chemical Company
Maleic Anhydride	PDS 51300-AB (Rev. C)	Fisher Scientific Company
Niobium Pentachloride	(1) PDS 30052-C	Atomergic Chemetals (CIBA), P. O. No. 59-NUB-80372 & 90177
	(2) GFE (S.O.Y. 84327)	Union Carbide Nuclear Corpora- tion, Y-12 Plant
	(3) 33Y-7266V	Union Carbide Nuclear Corpora- tion, Y-12 Plant
Anhydrous Hydrogen Chloride	PDS 52217-Ap (Sub B)	Frontier Chemical Company, Air Products and Chemicals
Hydrogen	PDS 3057-F	Air Products and Chemicals
Argon	PDS 52118-BA (Sub A)	Air Reduction Sales
Molybdenum Hexacarbonyl	PDS 30095	Climax Molybdenum Company
Transition Tip	910E185	WANL
Brazing Powder (For Tips)	PDS 30179-1	Fansteel Metallurgical Corpora- tion
Niobium Carbide Powder	PDS 30104-D	Kawecki Chemical Company

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TABLE 2 (CRD)
PEWEE I PROCESS PROCEDURES (U)

AFF No.	Title
1. 1010	Material Preparation and Dry Carbon Ingredient Blending
2. 1013	Procedure For Proof Testing Strength of Brazed Joint at Element/Tip Interface
3. 1020	Catalyzed Binder Preparation
4. 1025	Batch Formulation
5. 1030	Mixing Procedure
6. 1040	Extrusion Procedure
7. 1050	Cure Procedure
8. 1060	Bake Procedure
9. 1065	Procedure for Induction Brazing Tips to As-Graphitize Elements
10. 1066	Procedure for Cantilever Shear/Flexure Testing Ultimate Strength of Tip Brazing Operator Qualification Samples
11. 1070	Graphitizing Process for Unfueled and Fueled Graphite Shapes (35-Element "E" - Furnace)
12. 1080	Procedure for Leaching of Fueled Graphite Shapes
13. 1091	Coating of Unfueled Graphite Support Blocks, Insulating Cups, and Washers
14. 1095	Sequential Bore/O.D. Coating of Fueled Graphite Shapes
15. 1110	Procedure for Packing and Shipment of Final Machined and Coated Elements
16. 1140	Final Bore Processing of Fueled Graphite Shapes
17. 1160	Procedure for Loading Low Temperature Furnace Saturators
18. 1270	Graphitizing Process for Fueled and Unfueled Graphite Shapes (74-Element "AE" - Furnace)

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TABLE 3 (CRD)

PW-1 ORDERING SUMMARY - ELEMENTS (U)

Code	Drawing	Processing Suppliers	Order	Last C/N	Quantity		Coating Variable	Bore Variable	Length Backcoat	Tip Length Composite	Matrix Variable
					Ord.	Del.					
525	G06M	W-W	77507	27	10	18	GED + "X"	110	48.5" Min.	1"	Impregnate
525	G21M	W-W	77507	27	10	6	GEM	110	48.5" Min.	1"	Impregnate
525	G05M	W-W	77507	27	16	47	GED + "X"	110	48.5" Min.	1"	Standard
525	G25M	W-W	77507	27	11	7	GEM	112	48.5" Min.	1"	Standard
477	G04M	Y-W	77507	27	14	24	GED + "X"	110	48.5" Min.	1"	Additive
277	G24M	Y-W	77507	27	10	6	GEM	112	48.5" Min.	1"	Additive
269	G07M	Y-W	77507	27	8	22	GED + "X"	110	48.5" Min.	1"	Additive
269	G22M	Y-W	77507	27	9	14	GEM	110	48.5" Min.	1"	Additive
Impregnate - Nb Resonate Additive - 2.5 NbC											
525		W-Y	77507	5	50	40	Shipped as Impregnated-Regraphitized WNCO participation in matrix exchange - basic core elements.				

TABLE 4 (CRD)

BI-WEEKLY SUMMARY OF PW-1 FUEL ELEMENT MANUFACTURING
CORE CANDIDATE ELEMENTS ONLY PLUS LASL SAMPLES (U)

Week Ending	Extrude	First Machine	Peripheral Coat	Final Machine	X-Coat	Final Inspection	Ship to LASL
12-7-67	267	0	0	0	0	0	0
12-21-67	58	0	0	0	0	0	0
1-4-68	0	0	0	0	0	0	0
1-18-68	0	96	0	0	0	0	0
2-1-68	0	176	0	0	0	0	0
2-15-68	0	87	11	0	0	0	0
2-29-68	0	79	66	11	0	0	0
3-14-68	0	35	91	107	52	27	0
3-28-68	0	0	45	95	75	64	4
4-11-68	0	0	0	0	0	110	111
4-25-68	0	0	0	0	0	0	42
Total	325	473	213	213	127	201	157

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TABLE 5 (CRD)
FINAL PW-1 YIELDS
CORE CANDIDATE ELEMENTS ONLY (U)

Process Stage	No. of Elements Through Stage	Yields to Work Order
Extrude and Cure	325	3.34
Bake	325	3.34
Graphitize	325	3.34
Tip	478*	3.32
First Machine	473	3.28
First Inspection	473	3.28
Leach	452	3.14
Leach Inspection	452**	3.14
Furnace Processing	213	1.48
Final Machining	213	1.48
Nb Inspection	213	1.48
X-Coat	127***	1.14
Final Inspection	201	1.40
Ship to LASL (Core)	144	1.00
Ship to LASL (Samples)	13	----
Ship to WANL (Spec Samples)	12	----
Ship to WANHES (Corr. Test)	51	----
Ship to Y-12 (As-Leach)	40	----

* Includes 155 received from Y-12.

** Includes 40 shipped to Y-12.

*** Yield based on shipment quantity of 111 as-"X"-coated.

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TABLE 6 (CRD)
ENGINEERING AND TEST EVALUATION ELEMENTS (U)

Requisitioning Section	Quantity Required	Quantity Delivered
Materials and Process Development	32	32
Materials Testing Coating Stress Analysis	31	31
EML Physical Property Testing	66	66
Fuel Development Coating Evaluation	14	14
TFL Corrosion Rig Development	4	4
MTLS Extended Tip Development	16	16
MTLS Physical Property Testing	20	20
WNCO Coating Development	8	8
WNCO Tip Braze Development	3	3
Program Control Pool Coated	<u>Bal.</u>	19
Uncoated		<u>7</u>
	Total	220

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TABLE 7 (CRD)

AXIAL SUPPORT HARDWARE (U)

Type	Style	WANL Drawing	Order	Last C/N	Quantity Processed	Quantity Shipped	Processed/Shipped Rate
Pedestal	Regular	929F015 GO1A	79241	5	63	56	1.13
Sleeve	Outer	981D375 HO2	79245	5	132	76	1.74
Cup	Outer	981D371 HO1	79246	3	46	41	1.12
Cup	Long Outer	981D371 HO2A	79246	3	14	10	1.40
Cup	Pyro	981D391 HO2B	77452	5	78	48	1.62
Cup	Long Pyro	981D391 HO3B	77452	5	10	8	1.25
Washer	Tapered	981D368 HO1	79248	5	94	72	1.31

TABLE 8 (CRD)
PEWEE-I ELEMENT PERMEABILITY (U)

Supplier	Fuel Element Loading	Ranges of Leak Rate (cc/min.) (As-Leached)								Total Fuel Elements Evaluated
		0 - 99	%	100 - 169	%	170 - 199	%	200 - & Over	%	
WNCO	525	112	36	131	42	28	9	39	13	310
Y-12	477	34	44	43	56	0		0		77
Y-12	269	59	81	7	10	1	1	6	8	73

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TABLE 9 (CRD)

PEWEE-I EXTRUSION RUN (U)

	Extrusion Pressure (Tons)		Extrusion Rate (in./min.)	
	Average	Range	Average	Range
PEWEE I	93	85-105	101	93-124*
PEWEE I Tailings	105	95-120	102	93-109
* One batch extruded at 124 in./min. The next highest rate was 109 in./min.				

Type of Element	No. of Elements Extruded at 95 ± 10 Tons and 100 ± 10 in./min	No. of Elements Extruded at Pressure Higher Than 95 ± 10 Tons	No. of Elements Extruded at Rate Higher Than 100 ± 10 in./min
Batch	256	--	7
Tailing**	43	19	--

** Tailing elements were not extruded to the controlled pressure and rate.

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TABLE 10 (CRD)

PEWEE I "X"-COAT PRODUCTION RUNS (U)

"X" Run No.	NbC Run No.	F/E Type	No. of F/E	Avg. Wt. Dep.*	Avg. Wt. B/D**	Avg. Wt. Ret.***
AA-174	M-136	G05K (S)	17	4.97	0.88	4.09
	C-396	G05K (S)	18	5.07	0.99	4.08
AA-175	M-137	G07K (A)	17	4.92	1.11	3.81
	L-313	G06K (I)	16	5.01	0.45	4.56
AA-177	L-314	G05K (S)	18	5.05	1.20	3.85
	C-397	G07K (A)	16	4.93	0.42	4.51
AA-178	C-398	G06K (I)	17	4.96	0.55	4.41
	F-387	G05K (S)	18	5.15	0.80	4.35
AA-179	M-138	G04K (A)	17	5.04	0.76	4.28
	M-139	G04K (A)	17	5.35	1.15	4.20

S = Standard; I = Impregnated; A = Additive

* Average Weight Deposition = Average Weight of Mo deposited in the coating run.

** Average Weight B/D = Average Weight of Mo blown from the elements of a coating run in the room temperature blowdown cycle.

*** Average Weight Retention = Average Weight of Mo remaining in the elements of a coating run as shipped.

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