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WANL-TME-1847

January 1969

Westinghouse Astronuclear Laboratory

FINAL REPORT
FUEL DEVELOPMENT TEST SPECIFICATION
PHASE IV-A
QUALIFICATION COATING PROCESS

(Title Unclassified)

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IL-TME-1847

May 1969

Classification cancelled (or changed to _____)

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by H.F.C. TIC, date 3/20/83

Westinghouse Astronuclear Laboratory

FINAL REPORT
FUEL DEVELOPMENT TEST SPECIFICATION
PHASE IV-A
QUALIFICATION COATING PROCESS

(Title Unclassified)

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SPECIAL REVIEW		
FINAL DETERMINATION		
Class: <u>u</u>		

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ABSTRACT (U)

(CRD) The "GEM" process employs methane in the coating gas stream and deposition temperatures in the range of 1000° to 1100°C to coat fuel elements. The low coating temperature and the avoidance of carbon depletion in the graphite matrix combine to produce extremely adherent coatings. The concepts underlying this "GEM" process as deposited on a set of standard hi-void fraction fuel elements are described and the results of its implementation are presented.

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1.0 INTRODUCTION (U)

(CRD) For several years NERVA fuel elements have been coated with NbC by a diffusion process in which the carbon is supplied by the element matrix. This process has required coating temperatures in excess of 1400°C. Recently, it was found that satisfactory coatings could be obtained by lowering the temperature and adding methane to the coating gas as a carbon source for NbC.

(CRD) Fuel Development Test Specification Phase IV-A was initiated to assess the progress made in the development of this GEM* NbC coating process at the three facilities: WEFF, Y-12, and LASL. A set of high-void fraction fuel elements made by standard matrix fabrication procedures was provided by the WNCO facility. Twenty-eight (28) elements each, in the as-leached inspected condition, were shipped to LASL, Y-12, and WANL for NbC coating by their respective low temperature methane processes. The elements were distributed in five coating runs at each site. Elements were then shipped to WANL to obtain preliminary information on corrosion performance.

* From LASL terminology, the "G" indicates the entrance of process gases from the cold or serial number end of the element and the "M" indicates methane usage in the process gas.

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2.0 DESCRIPTION OF EXPERIMENT (U)

2.1 Matrix Processing (U)

(CRD) All the raw materials used in this experiment were consistent with current WANL Department Specifications. Fifteen (15) batches (numbers 5123 through 5135) of Code 20 fuel elements were extruded at WNCO. These elements were inscribed with sequential serial numbers from 431-1042219 through 431-1042328 and were tipped with standard non-fuel element stock from elements 000-1042163 through 000-1042170. Standard WNCO process procedures were followed through leach. Processing data are listed in Appendix A.

(U) After leaching, a visual examination for holes, cracks, and chips was performed and incremental helium and whole body air leak rates were taken. In addition, hot end dimensional measurements and incremental electrical resistances were taken.

(CRD) Only elements with a whole body leak rate under 100 cc per minute were selected for this experiment.

2.2 NbC Coating (U)

(CRD) In the GEM process, used by each of the three facilities, the coating gas is a mixture of Ar, HCl or HBr, H₂, CH₄, and

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either NbCl_5 or NbBr_5 . It is believed that two chemical reactions are involved:

(U) Equation 1 represents a gas phase reduction of NbCl_5 to a lower chloride. This lower chloride then reacts with CH_4 at the gas/solid interface, Equation 2, to produce a coating of NbC. No diffusion of carbon through the coating is required.

(U) The particular process used by each of the three facilities is different as described below.

2.2.1 Y-12 (U)

(CRD) The GEM process developed at Y-12 utilizes niobium pentabromide as the source of niobium. Hydrogen bromide is added to the gas stream to prevent the formation of Nb_2C or Nb.

(U) The mechanism of this system is similar to that of the chloride system and the resultant products are similar.

(U) Gas flow rates are identical to those used at WEFf during Phase IV-A coating. These values are given in Appendix B,

Table 2.

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(CRD) After receiving the twenty-eight (28) fuel elements from WANL, Y-12 personnel decided to re-leach eighteen (18) in hopes of obtaining a more complete leaching of all the exposed UC_2 beads. A leach temperature of $2100^{\circ}C$ was attained for one hour, followed by a lower temperature leach for an additional two hours. During this two-hour leach, the furnace was slowly cooled to $1700^{\circ}C$. The elements lost an additional one gram during the re-leaching operation. Metallographic samples taken from a Y-12 element in the run (not Phase IV-A) showed no increased UC_2 bead migration. The eighteen Phase IV-A elements were then delivered for bore coating.

(CRD) Three coating runs containing six elements each were made; each was to have a different NbC bore profile as follows:

1)	Run 1	2.0 mils at 17-1/2 inches and 2.2 mils at 47-1/2 inches
2)	Run 2	1.7 mils at 17-1/2 inches and 2.0 mils at 47-1/2 inches
3)	Run 3	2.2 mils at 17-1/2 inches and 2.5 mils at 47-1/2 inches

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(U) The OD surfaces on the first three runs were not coated. Five elements from each run were delivered to WANL for corrosion testing. The remaining two runs were scheduled for coating after corrosion testing of the first three had been completed. Test data from WANL indicated that NbC coating run 5444, profile 3 above, gave consistently good corrosion results. Therefore, a decision was made to coat the remaining ten (10) elements from Phase IV-A to obtain a profile similar to this NbC coating run.

(CRD) Prior to bore coating, elements in the last two runs were OD coated using the low temperature process. A nominal 12.8 grams of NbC was deposited on the OD surfaces using a coating time of eight hours. The elements were then bore coated in NbC coating runs 5452 and 5453. Results of these runs are listed in Appendix B, Table 2. They were inspected and shipped to WANL for corrosion testing.

2.2.2 WEFF Coating (U)

(U) The Westinghouse process for GEM NbC coating was developed using the chloride system. As mentioned

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earlier, gas flow rates are identical to Y-12. Temperatures and times were varied to produce thinner or thicker profiles as desired.

(U) Due to a shortage of elements from the Phase IV-A specification, five elements were selected from the Phase IV-B program to fulfill the WANL requirement of twenty-eight (28) elements. The five elements selected met all the necessary requirements of Phase IV-A.

(CRD) A total of five (5) NbC coating runs was scheduled, with each run having a different NbC bore profile. The original plan at WANL was to produce the following profiles:

1) Run 1	1.5 mils at 20 inches and 2.8 mils at 50 inches
2) Run 2	2.2 mils at 20 inches and 3.4 mils at 50 inches
3) Run 3	1.7 mils at 20 inches and 2.8 mils at 50 inches
4) Run 4	1.0 mils at 20 inches and 2.5 mils at 50 inches
5) Run 5	1.2 mils at 20 inches and 3.0 mils at 50 inches

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(U) The coating run data and the profiles obtained are listed in Appendix B, Table 1. The bore profiles of three runs were too thin and these elements were recoated; B-210 was recoated in G-90, B-211 and B-212 were recoated in B-213.

(CRD) All the WEFF Phase IV-A elements were OD coated using the GEM process. Fixtures were used in which the OD and bores were coated sequentially in a single furnace run. The OD was coated first. Varying results were obtained with the OD coating since GEM OD was a new process at WEFF during the Phase IV-A campaign. Reasonable control of the process to obtain a 0.3 to 0.7 mil coating thickness was established near completion of these runs.

2.2.3 LASL (U)

(CRD) LASL deviated from the original intent of the Phase IV-A program of singly depositing a GEM NbC coating to experiment with a new approach to coating technology. Their intent was to deposit a duplex GEM/GED NbC coating and by doing so, capitalize on the favorable features of both.

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(CRD) In this process, a thin GEM coating of about 1 mil at 10 inches, 1.8 mils at 25 inches, and 0.7 mil at 40 inches was applied to the element. After that, a diffusion NbC coating was applied which primarily built the hot end thickness to approximately 2.5 mils.

(CRD) Six coating runs were made. It should be mentioned that two or three cycles were required for each step, depending on whether the elements were OD coated in addition to bore coating with GEM and GED. There were three elements in each of five runs and one in the sixth. A total of 16 elements were coated. Pertinent data are listed in Appendix B, Table 3.

3.0 DISCUSSION OF RESULTS (U)

(CRD) Some difficulty in obtaining complete control of the GEM coating process before and during the interim Phase IV-A period was experienced by all three facilities. A preliminary analysis of the GEM system indicated that within certain limits the deposition rate of NbC was a linear function of the methane flow and temperature. This theory was substantiated by the fact that difficulty in preventing coating thickness peaks near station 40 using a gas chemistry consisting of 0.020 liter per minute per element flow of methane was experienced.

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It appeared that near station 40, the methane in the gas stream had been depleted to a point where further temperature increases were insufficient to produce a linear profile. By increasing run times at Y-12 and by recoating at WANL, the problem was overcome.

(CRD) The LASL process involved a GEM midband followed by GED hot end coating. This duplex coating proved beneficial in that it combined the excellent adherence characteristics of GEM type coatings in the midband region and provided a better type of coating at the hot end of the element.

(CRD) Samples were taken to determine the NbC stoichiometry. The X-ray diffraction results indicated C/Nb ratios varying from 0.86 to 0.92. No Nb₂C or Nb phases were found.

(U) A detailed metallographic examination of as-coated and as-tested elements was pursued, and a number of noteworthy observations were made.

(CRD) One of the characteristic features of the GEM NbC coating process was its greater surface roughness as compared to a more familiar diffusion process coating.⁽¹⁾ See Figures 1.a and 1.b. Some of the coatings made during early GEM development and during Phase IV-A were very rough and occasionally contained nodular growths which

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extended into the coolant channels. Two types of nodules have been observed in GEM coatings to date, one arising from accelerated deposition on carbon flakes and a second occurring as a single crystal of NbC.⁽¹⁾ Both types are shown in Figures 1.c and 1.d.

(CRD) The roughness and nodular growths into the coolant channels resulted in a smaller channel diameter in the air flow test. As expected, during post-coating inspection of Phase IV-A elements, the air flow test showed decreasing hole diameters with increasing NbC weight such that the air impedance values would not meet conventional specification requirements. Both Y-12 and WANL experienced the same difficulty.

(CRD) Y-12 developed a process for diamond honing the bores to produce coatings within current WANL specifications. Two elements from each of the last two Phase IV-A batches coated at Y-12 were honed to obtain air impedance values above 0.1020 inch. Subsequent evaluations indicated this technique led to bore damage on the elements and it was discontinued from further test specifications.

(1) MFD:RL:2788, dated February 15, 1968.

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a. Station 20
Element 431-43750 Batch G-94

200X

b. Station 40
Element 431-43750 Batch G-94

200X

c. Nodular Growth at Carbon Sites
Element 09-81755 Batch B-207

400X

d. Nodular Growth as Single Crystal
Element 431-42635 Batch G-81

400X

Figure 1. (CRD) GEM Coatings (U)

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(CRD) Because of the problem with low air impedance values, some measurements were made of physical channel diameter and coating thickness at various positions along the coated element. Figure 2 is a plot of these data. The relationship between channel diameter and coating thickness is shown in Figure 3. These results indicate a roughness factor of about 25%.

(CRD) The surface irregularities of the GEM coating caused the envelope dimensions of the OD coated element to be larger than expected. Envelope dimensions before and after coating were compared with metallographic coating thicknesses for twenty-six (26) elements from seven development runs⁽²⁾, five of which were IV-A. Although the data scattered considerably, coating thicknesses calculated from envelope dimensions averaged 50% larger than metallographic thicknesses, e.g., a 0.5 mil metallographic thickness would change the envelope dimension by 1.5 mils.

(2) MFD:JW:2910, dated March 25, 1968.

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Figure 2. (CRD) Variations of Channel Diameter and Coating Thickness in GEM Coatings (CRD)

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Figure 3. (CRD) Relationship Between Channel Diameter and Coating Thickness in GEM Coatings (CRD)

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(CRD) Cracking of the graphite matrix was revealed by metallographic examination of element cross sections. These cracks result from the tensile stresses induced upon cooling from coating temperature to room temperature since the thermal expansion coefficient of the coating is higher than the matrix. To produce these matrix cracks the coating must adhere to the graphite. When the adherence is marginal as with diffusion coatings, matrix cracks are not normally observed, but with GEM coatings where adherence is excellent coating cracks propagate into the matrix. The exact path or shape the crack takes is dependent upon the matrix make-up in its immediate vicinity as shown in Figure 4. These matrix cracks are normally observed near the hot end of the element since higher stresses are exerted by the thicker coatings. The incidence of hot end cracking on several Phase IV-A elements during corrosion testing indicates that these matrix cracks can have a deleterious effect on element performance.

(CRD) The GEM/GED process used by LASL showed better performance at the hot end because of the absence of matrix cracks. Coating cracks in the midband of these elements are small and few, therefore ideal. The additional deposition of GED NbC coating at the hot end supposedly relieves any stresses imposed by GEM coating by utilizing

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a small portion of the underlying graphite matrix in that region.

This produces an ideal hot end condition; therefore, overall corrosion performance should be improved by this process.

(CRD) Incremental electrical resistance was determined on all elements after leaching and on all Y-12 and WANL elements after NbC coating. A resistance profile was also taken on all available corrosion tested elements. The resistances along the length of an as-leached element exhibited a relatively flat profile corresponding to an average of about 20 milliohms per inch. This corresponds to a specific resistance of about 1600 milliohms -cm. The resistance profile after coating was dependent on the coating thickness, number of cracks, and adherence to the matrix.

(U) A typical resistance profile in the as-leached, coated, and corrosion tested condition is shown in Figure 5.

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a) Matrix Crack Through Matrix

b) Matrix Crack Around Graphite Flake

Figure 4. (CRD) Matrix Cracking in GEM-Coated Elements
Element 525-57008, Batch G-96, 400X (U)

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Figure 5. (CRD) Typical Resistance Profile of GEM Coating (U)

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(U) The fuel element data from the hydrogen corrosion tests are presented in Appendix C. The weight loss, total pinholes, failure location, planned test times, and actual test times are summarized.

(CRD) Testing of Y-12 and WEFF-coated elements was performed at the WANHES facility, while the LASL elements were tested at their facility. Chucking and mechanical problems accounted for several failures for both Y-12 and WEFF elements, although, in general, test data from the LASL GEM/GED duplex coating indicated superior performance when compared to an all GEM coating. Of a total of nineteen tests of WEFF-coated elements, none tested for the required time in the R1.02 test and only six met the time requirement in the A6.02 test. Y-12 had eighteen Phase IV-A elements tested. Three passed the R1.02 test and six passed the A6.02 test. LASL tested five elements at R1.02 conditions. Three tested for three twenty-minute cycles. Six elements were given a 20 + 20 minute test and five of these passed. A single 20 minute test also performed satisfactorily.

(U) Pinholing did not seem to be a major problem in testing, although incidence of pinholing tended to be slightly greater for Y-12 and WEFF coated elements.

(CRD) Several of the Y-12 and WEFF elements displayed binder carbon attack in channel ten.

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(CRD) It was apparent after reviewing the data that both Y-12 and WEFF elements performed better when coating thicknesses were greater than one mil at twenty inches and also when thicknesses were over 2.5 mils at fifty inches. It should be noted that considerable breakage and cracking was observed near the hot end of many elements.

(CRD) Examination of GEM bore-coated elements after corrosion testing has revealed grain growth of the niobium carbide⁽³⁾. Although definitive correlations between time, temperature, and growth rate have not been made, it appears that significant grain growth occurs at temperatures in excess of 2100°C. Heat treatments have been performed on three mil GEM coats at 2300°C for periods of one and three hours. Figure 6 shows the progressive grain growth as a function of time.

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(CRD) The particular coating under study had a two phase as-coated structure as shown in Figure 6.a and became homogeneous upon heat treatment. The large void areas at the intersections of grain boundaries in Figures 6.b, 6.c, and 6.d are probably a collection of vacancies from the original grain boundaries. Not all GEM coatings have the two phase as-coated structure shown in Figure 6.a, but all GEM coatings produced under present coating conditions exhibit grain growth when heat treated at high temperatures. The significance of

(3) MFD:RL:2864, Subject: Metallography Report, dated March 12, 1968.

a) As-Coated Structure

b) 1 Hour At 2300°C

c) 3 Hours At 2300°C

d) Very Large Grain, 3 Hours At 2300°C

Figure 6. (CRD) Structural Changes in GEM Niobium Carbide Bore Coatings as a Function of Heat Treatment, Element 000-81755, Batch B-207, Station 30, 400X (CRD)

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grain growth on the corrosion properties of the GEM coated elements is not known.

(U) Only a limited number of air impedance measurements were taken of post-corrosion tested elements. These data are presented in Appendix D. They show that no significant change occurs in channel diameter during corrosion testing.

4.0 CONCLUSIONS (U)

(U) Test Specification Phase IV-A was a successful program in that it laid the groundwork for defining a coating process that could be used for the larger coating comparison program Phase IV-B and for PEWEE I production coating.

~~(S)~~ The GEM coating has the advantage of excellent adherence and a fine crack structure. Its low deposition temperature and the potential shorter coating run times make it a desirable coating from an operational standpoint.

~~(S)~~ The major disadvantage of this process is the cracking. However, by combining GEM coating technology to a combination GEM/GED duplex process as demonstrated at LASL, it should be possible to provide a fuel element superior to any presently available.

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APPENDIX A ([REDACTED])
PROCESSING DATA SUMMARY (U)

RAW MATERIALS USED IN MATRIX FABRICATION (U)

Fuel Particles - Typical GA, WANL Specification PDS 30050-D (U)

Loading - Code 20 per NRX-A6R Drawing 938J660 (U)

Flour - Great Lakes 89772 (Master Blend No. 20, WANL Specification PDS 30046-B (U)

Thermax 82945 (Master Blended), WANL Specification PDS 30047-B (U)

Varcum - Single Lot, Typical, WANL Specification 30048-B (U)

Maleic Anhydride - WANL Specification PDS 51300 AB-C (U)

(CDD) PROCESSING DATA FOR WANL ELEMENTS (U)

<u>Element S/N</u>	<u>Extrusion No.</u>	<u>Cure No.</u>	<u>Bake No.</u>	<u>Graph No.</u>	<u>Leach No.</u>	<u>NbC Run No.</u>	<u>Whole Body Air cc/min</u>	<u>Elements Corrosion Tested (Indicated By *)</u>
431-1042221	5123	N-183	J-494	EA-23	S-93	G-88	29	
431-1042224	5124	N-183	J-494	EA-23	S-93	G-88	30	*
431-1042226	5124	N-183	J-498	EA-23	S-93	G-88	50	*
431-1042255	5127T	G-396	JA-24	EA-24	S-93	G-88	10	*
431-1042258	5127T	G-396	JA-24	EA-24	S-93	G-90	34	
431-1042259	5127T	G-396	JA-24	EA-24	S-93	G-90	30	*
431-1042265	5128	G-396	JA-24	EA-24	S-93	G-90	17	*
431-1042267	5128	G-396	JA-24	EA-24	S-93	G-88	90	*
431-1042268	5128	G-396	JA-24	EA-24	S-93	G-90	70	*
431-1042269	5128	G-396	JA-24	EA-24	S-93	G-89	62	*
431-1042294	5131	G-396	JA-24	EA-24	D-552	G-89	27	*
431-1042295	5131	G-396	JA-24	EA-24	D-552	G-89	38	*
431-1042299	5132	G-396	JA-24	EA-24	D-552	B-213	30	*
431-1042303	5132	G-396	JA-24	EA-24	D-552	B-213	40	
431-1042233	5125	N-183	J-494	EA-23	S-94	B-213	104	*
431-1042241	5126	G-396	JA-24	EA-24	S-93	G-89	100	*
431-1042242	5126	G-396	JA-24	EA-24	S-94		100	

(ORD) PROCESSING DATA FOR WANL ELEMENTS (U)

<u>Element S/N</u>	<u>Extrusion No.</u>	<u>Cure No.</u>	<u>Bake No.</u>	<u>Graph No.</u>	<u>Leach No.</u>	<u>NbC Run No.</u>	<u>Whole Body Air cc/min</u>	<u>Elements Corrosion Tested (Indicated By *)</u>
431-1042314	5134	G-396	JA-24	EA-24	D-552	B-213	105	*
431-1042320	5134	G-396	JA-24	EA-24	S-94		105	
431-1042227	5124	N-183	J-494	EA-23	S-93	B-213	47	*
431-1042234	5125	N-183	J-494	EA-23	S-93	B-213	32	
431-1042304	5132	G-396	JA-24	EA-24	D-552	B-213	67	*
431-1042655	5167	N-186	J-498	E-995	D-564	B-213	22	*
431-1042759	5127	N-186	J-498	E-995	D-564	B-213	32	*
431-1042660	5167	N-186	J-498	E-995	D-564	B-213	27	*
431-1042661	5167	N-186	J-498	E-995	D-564	G-89	24	*
431-1042662	5167	N-186	J-498	E-995	D-564	G-90	21	*
431-1042297	5131	G-396	JA-24	EA-24	D-552	5453	46	*
431-1042312	5133	G-396	JA-24	EA-24	D-552	5452	92	*
431-1042220	5123	N-183	J-494	EA-23	S-94	5444	12	
431-1042223	5124	N-183	J-494	EA-23	S-94	5443	32	*
431-1042281	5130	G-396	JA-24	EA-24	S-94	5442	18	
431-1042322	5135	G-396	JA-24	EA-24	S-94	5443	72	
431-1042324	5135	G-396	JA-24	EA-24	S-94	5442	54	
431-1042325	5135	G-396	JA-24	EA-24	S-94		60	

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(C) PROCESSING DATA FOR WANL ELEMENTS (U)

<u>Element S/N</u>	<u>Extrusion No.</u>	<u>Cure No.</u>	<u>Bake No.</u>	<u>Graph No.</u>	<u>Leach No.</u>	<u>NbC Run No.</u>	<u>Whole Body Air cc/min</u>	<u>Elements Corrosion Tested (Indicated By *)</u>
431-1042326	5135	G-396	JA-24	EA-24	S-94	5444	84	
431-1042301	5132	G-396	JA-24	EA-24	D-553	5453	26	*
431-1042302	5132	G-396	JA-24	EA-24	D-553	5453	27	
431-1042310	5133	G-396	JA-24	EA-24	D-553	5452	27	*
431-1042313	5133	G-396	JA-24	EA-24	D-553	5453	83	*
431-1042277	5129	G-396	JA-24	EA-24	D-552	5442	55	*
431-1042278	5129	G-396	JA-24	EA-24	D-552	5453	49	*
431-1042279	5129	G-396	JA-24	EA-24	D-552	5453	45	
431-1042280	5130	G-396	JA-24	EA-24	D-552	5444	54	
431-1042282	5130	G-396	JA-24	EA-24	D-552	5442	31	*
431-1042283	5130	G-396	JA-24	EA-24	D-552	5444	56	
431-1042285	5130	G-396	JA-24	EA-24	D-552	5443	57	
431-1042287	5130	G-396	JA-24	EA-24	D-552	5444	56	
431-1042252	5127T	G-396	JA-24	EA-24	S-93	5443	14	*
431-1042262	5127T	G-396	JA-24	EA-24	S-93	5452	20	*
431-1042251	5127	G-396	JA-24	EA-24	S-93	5442	48	*
431-1042256	5127T	G-396	JA-24	EA-24	S-93		10	
431-1042254	5127T	G-396	JA-24	EA-24	S-93	5442	7	*

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<u>Element S/N</u>	<u>Extrusion No.</u>	<u>Cure No.</u>	<u>Bake No.</u>	<u>Graph No.</u>	<u>Leach No.</u>	<u>NbC Run No.</u>	<u>Whole Body Air cc/min</u>	<u>Elements Corrosion Tested (Indicated By *)</u>
431-1042260	5127T	G-396	JA-24	EA-24	S-93	5444	29	
431-1042261	5127T	G-396	JA-24	EA-24	S-93	5452	28	*
431-1042263	5128	G-396	JA-24	EA-24	D-552		28	
431-1042316	5134	G-396	JA-24	EA-24	D-552	181/182/183	66	*
431-1042306	5132	G-396	JA-24	EA-24	D-552	173/174/175	37	*
431-1042298	5131	G-396	JA-24	EA-24	D-552	176/177	38	*
431-1042257	5127T	G-396	JA-24	EA-24	S-94		22	
431-1042289	5130T	G-396	JA-24	EA-24	S-94		21	
431-1042272	5129	G-396	JA-24	EA-24	S-94	176/177	26	*
431-1042235	5125	N-183	J-494	EA-23	S-94		28	
431-1042237	5126	N-183	J-494	EA-23	S-93	173/174/175	36	*
431-1042273	5129	G-396	JA-24	EA-24	S-94		37	
431-1042292	5131	G-396	JA-24	EA-24	S-94	178/179/180	14	*
431-1042307	5132	G-396	JA-24	EA-24	D-552		32	
431-1042293	5131	G-396	JA-24	EA-24	D-552	186/187	26	*
431-1042291	5131	G-396	JA-24	EA-24	D-552	178/179/180	33	*
431-1042231	5125	N-183	J-494	EA-23	S-93		26	
431-1042232	5125	N-183	J-494	EA-23	S-93		78	

~~(S)~~ PROCESSING DATA FOR WANL ELEMENTS (U)

<u>Element S/N</u>	<u>Extrusion No.</u>	<u>Cure No.</u>	<u>Bake No.</u>	<u>Graph No.</u>	<u>Leach No.</u>	<u>NbC Run No.</u>	<u>Whole Body Air cc/min</u>	<u>Elements Corrosion Tested (Indicated By *)</u>
431-1042236	5125	N-183	J-494	EA-23	S-93		45	
431-1042243	5126	G-396	JA-24	EA-24	S-93	181/182/183	33	*
431-1042245	5127	G-396	JA-24	EA-24	S-94		31	
431-1042246	5127	G-396	JA-24	EA-24	S-93		30	
431-1042247	5127	G-396	JA-24	EA-24	S-93		36	
431-1042249	5127	G-396	JA-24	EA-24	S-93	186/187	66	*
431-1042250	5127	G-396	JA-24	EA-24	S-93		60	
431-1042239	5126	N-183	J-494	EA-23	S-93		30	
431-1042253	5127T	G-396	JA-24	EA-24	S-94		20	
431-1042266	5128	G-396	JA-24	EA-24	S-94		40	
431-1042270	5128	G-396	JA-24	EA-24		189/190/191	64	*
431-1042275	5129	G-396	JA-24	EA-24	D-552		62	

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APPENDIX B ()

NbC COATING DATA AND RESULTS (U)

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TABLE I (GRD)
RUN CONDITIONS AND COATING CHARACTERIZATION FOR WESTINGHOUSE COATING RUNS (U)

Run No.	Coat Cycle	Feed Gas Flows					Total Feed Gas	Time Hrs.	Temperatures				Avg. ΔW Gms.	Coating Thickness						Coating Thickness						Stoichiometry	
		SLPMPE							Corr. - °C					Metallography - (Mils)						Beta Backscatter - (Mils)							
		Ar	HCl	H ₂	CH ₄	NbCl ₅			8.5"	27"	52"	0"		10"	20"	30"	40"	50"	0"	10"	20"	30"	40"	50"	20"		
G-88	OD	4.5	0.75	0.077	0.020	0.088	5.44	4	1030	1043	1049	-	0	0.3	0.5	0.3	0.2	0.1	0	0.4	0.5	0.3	0.2	0.1	-	-	
G-88	Bore	4.5	0.75	0.077	0.020	0.089	5.44	22	1021	1086	1157	108.4	0.68	0.8	1.6	2.8	3.5	2.1	0.6	0.8	1.6	2.7	3.1	2.7	0.91	0.92	
B-210	OD	4.5	0.75	0.077	0.016	0.088	5.43	4	1022	1040	1037	-	0.0	0.1	0.1	0.1	0.1	0.4	0	-	-	-	-	-	-	-	
B-210	Bore	4.5	0.75	0.077	0.020	0.09	5.44	22	1040	1085	1137	72.1												0.9	0.9		
G-90	B-210 Recoat	4.5	0.75	0.077	0.020	0.088	5.44	12	999	1051	1112	31.9	0.7	0.8	2.0	2.4	2.8	3.2	0.65	1.0	2.1	2.6	2.7	2.9	0.87	0.87	
G-89	OD	4.5	0.75	0.077	0.020	0.124	5.47	3.3	1031	1044	1047	-	0.3	0.5	0.4	0.3	1.0	0.1	0.3	0.6	0.4	0.3	0.1	0.1	-	-	
G-89	Bore	4.5	0.75	0.077	0.020	0.088	5.44	24.7	1041	1093	1033	102.2	0.7	1.2	2.2	2.9	2.9	2.3	0.6	1.1	2.2	2.6	2.4	2.1	0.87	0.88	
B-211	OD	4.5	0.75	0.077	0.020	0.087	5.43	4	1010	1034	1041	-	0	0.1	0.2	0.1	0.1	0.1	0	0.2	0.3	0.3	0.2	0.4	-	-	
B-211	Bore	4.5	0.75	0.077	0.020	0.087	5.43	22	1013	1055	1103	51.5	0.2	0.3	0.5	0.7	1.1	1.6	-	-	-	-	-	-	0.86	0.87	
B-213	B-211 Recoat	4.5	0.75	0.077	0.020	0.088	5.44	14	991	1028	1059	22.0	0.6	0.6	1.1	1.5	1.8	2.6	0.6	0.6	1.0	1.6	1.8	2.6	0.87	0.88	
B-212	OD	4.5	0.75	0.077	0.020	0.088	5.44	4	1018	1039	1044	-	0.2	0.1	0.3	0.2	0.1	0.1	0	0.2	0.3	0.3	0.2	0.4	-	-	
B-212	Bore	4.5	0.75	0.077	0.020	0.088	5.44	22	1022	1063	1105	56.5	0.2	0.6	0.8	1.0	.9	1.1	-	-	-	-	-	-	0.87	0.86	
B-213	B-212 Recoat	4.5	0.75	0.077	0.020	0.088	5.44	14	991	1028	1059	26.0	0.7	0.8	1.6	1.8	1.9	2.5	0.6	0.7	1.5	1.7	1.8	2.2	0.87	0.87	

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TABLE 2
RUN CONDITIONS AND COATING CHARACTERIZATION FOR Y-12 COATING RUNS (U)

Run No.	Coat Cycle	Feed Gas Flows					Run Time Hrs.	Total Feed Gas	Temperatures Corr. °C			Avg. ΔW Gms.	Coating Thickness Beta Back Scatter Mils					
		Ar	HBr	SLPMPE H ₂	CH ₄	NbBr ₅			8.5"	27"	52"		2.5"	7.5"	22.5"	32.5"	42.5"	47.5"
5442	Bore	4.5	0.75	0.077	0.020	0.089	24	5.43	1060	1135	1175	88.0	0.8	1.1	2.0	2.0	2.1	2.2
5443	Bore	4.5	0.75	0.077	0.020	0.088	21	5.43	1060	1135	1175	76.3	0.8	0.9	1.3	1.6	1.7	1.7
5444	Bore	4.5	0.75	0.077	0.020	0.088	30	5.43	1060	1135	1175	111.9	1.1	1.4	1.9	2.4	2.6	2.6
6541	OD	4.5	0.75	0.077	0.020	0.089	8	5.43	1040	1130	1175	13.0	0.5	0.5	0.7	1.0	1.6	1.7
5452	Bore	4.5	0.75	0.077	0.020	0.089	27.5	5.43	1060	1136	1178	104.9	1.0	1.4	1.9	2.2	2.2	2.3
5453	Bore	4.5	0.75	0.077	0.020	0.088	28	5.43	1062	1136	1177	104.7	1.1	1.5	2.0	2.3	2.2	2.3

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TABLE 3 (CRD)
RUN CONDITIONS AND COATING CHARACTERIZATION FOR LASL COATING RUNS (U)

Run No.	Type Coating	Coat Cycle	Feed Gas Flows					Run Time Hrs.	Temperatures Corr. °C			Avg. ΔW Gms.	Coating Thickness Beta Back Scatter Mils					
			SLPMPE						8.5"	27"	52"		2.5"	7.5"	22.5"	32.5"	42.5"	47.5"
			Ar	HCl	H ₂	CH ₄	NbCl ₅											
B3-173	GEM	Bore	2.22	0.42	0.042	0.042	.055	6	1050	1120	1150	48.8	0.8	1.0	1.8	1.3	0.6	0.4
B3-174	GED	Bore	2.34	0.278	0.078	-	0.056	12	1020	1270	1780	27.5	0.8	1.0	0.6	0.8	1.9	2.6
									FINAL			76.3	1.6	2.0	2.4	2.1	2.5	3.0
B3-175	GED	OD	2.5	0.278	.125	-	0.074	6	1140	1250	1450	10.5	-	-	-	-	-	-
B3-176	GEM	Bore	2.22	0.42	0.042	0.042	0.052	6	1040	1110	1180	40.8	0.6	0.6	1.4	1.2	0.7	0.4
B3-177	GED	Bore	2.34	0.278	0.083	-	0.056	12	1000	1275	1750	21.9	0.4	0.5	0.1	0.2	1.0	1.9
									FINAL			62.7	1.0	1.1	1.5	1.4	1.7	2.3
B4-186	GEM	Bore	Not Available					N/A	1040	1100	1150	N/A	1.1	1.1	1.8	0.9	0.2	0.1
B4-187	GED	Bore	Not Available					N/A	1000	1275	1730	N/A	0.5	0.7	0	0.4	1.2	1.9
									FINAL			63.4	1.6	1.8	1.8	1.3	1.4	2.0
B4-189	GEM	Bore	Not Available					N/A	1035	1100	1150	N/A	0.6	0.8	1.5	1.0	0.4	0.2
B4-190	GED	Bore	Not Available					N/A	1010	1310	1750	N/A	0.3	0.4	0.1	0.3	1.2	2.0
									FINAL			N/A	0.9	1.2	1.6	1.3	1.6	2.2
B4-191	GED	OD	Not Available															

TABLE 3 (CDD)
(CONTINUED)

Run No.	Type Coating	Coat Cycle	Feed Gas Flows					Run Time Hrs.	Temperatures Corr. °C			Avg. ΔW Gms.	Coating Thickness Beta Back Scatter Mils					
			Ar	HCl	SLPMPE H ₂	CH ₄	NbCl ₅		8.5"	27"	52"		2.5"	7.5"	22.5"	32.5"	42.5"	47.5"
B5-178	GEM	Bore	2.24	0.42	0.042	0.042	0.052	6	1035	1100	1150	46.5	1.2	1.2	1.7	1.0	0.2	0.1
B5-179	GED	Bore	2.33	0.277	0.083	-	0.047	13	1015	1290	1730	33.3	0.2	0.3	0.1	0.4	0.7	2.2
									FINAL			79.8	1.4	1.5	1.8	1.4	1.9	2.3
B5-180	GED	OD	2.5	0.277	0.125	-	0.082	6	1130	1240	1450	4.6	-	-	-	-	-	-
B5-178	GEM	Bore	2.24	0.42	0.042	0.042	0.052	6	1035	1100	1150	46.5	1.2	1.2	1.7	1.0	0.2	0.1
B5-182	GED	Bore	2.34	0.278	0.078	-	0.052	14	1010	1270	1730	19.6	-	-	-	0.4	1.7	2.5
									FINAL			66.1	1.2	1.2	1.7	1.4	1.9	2.6
B5-183	GED	OD	2.40	0.278	0.125	-	0.074	6	1130	1245	1430	6.6	-	-	-	-	-	-

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APPENDIX C (~~_____~~)

CORROSION TEST RESULTS (U)

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(~~CONF~~) WANL ELEMENTS (U)

Batch No.	Element S/N	Test				Test Parameters			Test Results				
									$\Delta W(g)$	Corrected $\Delta W(g)$			BAR (%)
		No.	Desig.	Aim (Min.)	Duration (Min.)	Temp. at 48.6"($^{\circ}C$)	Power (K.W.)	H ₂ Flow S.C.F./min.		Pinholes			
										0-35	35-52	0-52	
G-88	431-1042224	1.b 1.2103	R1.02	20+20+20	20+20+4.8	2350	1222	858	24.9 N/A	3.63	5.22	8.85	80
Comments: Broke at 8-1/2" Corr. Hole - BAR Corroded up to 1-1/4 back.													
G-88	431-1042226	1.b 1.2104	R1.02	20+20+20	11.3	2380	1315	869	5.0 4.7	0.17	2.46	2.63	80
Comments: Abort, Loss of ΔP Holes at 49-5/8 Broke at 49-5/8 Unloading.													
G-88	431-1042255	1.b 1.2126	A6.02	30+30	30+22.5	2360 2350	965 976	595 596	25.0 11.6	1.89	5.73	7.62	0
Comments: Abort, Lost ΔP - BAR corroded. Broke at 50" unloading - mech.													
G-88	431-1042267	1.b 1.2156	A6.02	30+30	30+17.1	2385 2375	915 912	592 592	11.0 11.0	1.56	5.62	7.18	70
Comments: Abort 17.1, Chuck Failure - BAR Corroded to 5/8" Back.													
G-89	431-1042269	1.b 1.2105	R1.02	20+20+20	20+20+10	2380	1340	860	29.5 13.0	0.61	9.91	10.52	0
Comments: Abort, Loss of ΔP - BAR Corroded up to 1-1/4 Back.													
G-89	431-1042295	1.b 1.2106	R1.02	20+20+20	8.7	2420	1350	865	2.5 1.7				100
Comments: Abort - Loss of ΔP - Crack E Flat at 50-1/4.													

CONFIDENTIAL RESTRICTED DATA WANL ELEMENTS (U)

Batch No.	Element S/N	Test				Test Parameters			Test Results				
									ΔW(g)	Corrected ΔW (g)			BAR (%)
		No.	Desig.	Aim (Min.)	Duration (Min.)	Temp. at 48.6" (°C)	Power (K.W.)	H ₂ Flow S.C.F./min.		Pinholes			
										0-35	35-52	0-52	
G-89	431-1042294	1.b 1.2130	A6.02	30+30	30+7.3	2425 2385	930 904	592 597	$\frac{9.0}{8.7}$	.16	8.85	9.01	
Comments: Broke at 49-1/2 - Two large holes at 49-1/2 and 50".													
G-89	431-1042241	1.b 1.2155	A6.02	30+30	18.6	2385	928	600	$\frac{9.2}{8.8}$	0	6.23	6.23	80
Comments: Broke at 49-1/2 - Corrosion pocket all inside channels - BAR corroded to 1/4" back.													
G-89	431-1042661	1.b 1.2173	A6.02	30+30	30+30	2380 2375	934 925	595 596	$\frac{29.0}{15.7}$	-	-	-	0
Comments: BAR corroded up to 1" back.													
$\frac{G-90}{B-210}$	431-1042662	1.b 1.2118	A6.02	30+30	30+30	2335	936	593	$\frac{39.0}{13.9}$	3	9		0
Comments: BAR corroded up to 1-1/2" back - Medium surface corrosion 40 - 50".													
$\frac{G-90}{B-210}$	431-1042259	1.b 1.2158	A6.02	30+30	30+30	2375 2385	898 886	596 597	$\frac{13.0}{9.9}$	0.74	8.51	9.25	0
Comments: BAR corroded up to 3/8" back.													
$\frac{G-90}{B-210}$	431-1042265	1.b 1.2117	A6.02	30+30	30+30	2370	910	598	$\frac{22.0}{11.4}$	1.18	10.63	11.81	0
Comments: BAR corroded up to 1/2" back.													

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~~(CONF)~~ WANL ELEMENTS (U)

Batch No.	Element S/N	Test				Test Parameters			ΔW(g)	Test Results			
										Corrected ΔW (g)			BAR (%)
		No.	Desig.	Aim (Min.)	Duration (Min.)	Temp. at 48.6" (°C)	Power (K.W.)	H ₂ Flow S.C.F./min.		Pinholes			
0-35	35-52								0-52				
B-211 B-213	431-1042233	1.b 1.2119	A6.02	30+30	30+30	2335 2345	950 966	595 594	18.1	0.33	11.2	11.35 2	15
Comments: BAR corroded up to 3/4" back.													
B-211 B-213	431-1042660	1.b 1.2120	A6.02	30+30	30+30	2335 2380	870 885	603 600	20.0	3.02	8.43	11.45 1	0
Comments: Broke at 50" unloading - mech. BAR corroded up to 1" back.													
B-211 B-213	431-1042314	1.b 1.2132	R1.02	20+20+20	20+10.7	2380 2370	1390 1390	866 868	14.0 12.8	3.36	9.13	12.49 1	75
Comments:													
B-212 B-213	431-1042655	1.b 1.2121	A6.02	30+30	30+10.4	2370 2385	969 958	596 598	16.3	0	9.07	9.07 3	0
Comments: Abort 10.4 chuck corroded arcing at 49-3/4. BAR corroded to 1/2" back.													
B-212 B-213	431-1042659	1.b 1.2122	A6.02	30+30	11.2+18.8+ 30	2315 2385	973 928	597 595	31.0	3.84	13.83	17.67 1	0
Comments: Abort 11.2 chuck failure. Changed to Fec. No. 1. BAR corroded up to 1-1/2" back.													
B-212 B-213	431-1042227	1.b 1.2146	A6.02	30+30	9.0	2370	906	596	4.0 4.0			2	100
Comments: Broke at 36-1/4 unloading mech. Crack at 49-3/4 E Flat.													

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~~(S)~~ WANL ELEMENTS (U)

Batch No.	Element S/N	Test				Test Parameters			Test Results				
									ΔW(g)	Corrected ΔW (g)			BAR (%)
		Pinholes											
		No.	Desig.	Aim (Min.)	Duration (Min.)	Temp. at 48.6"(^o C)	Power (K.W.)	H ₂ Flow S.C.F./min.		0-35	35-52	0-52	
B-212 B-213	431-1042304	1.b 1.2157	A6.02	30+30	5.5	2370	897	598	$\frac{6.0}{6.0}$	0.72	1.33	2.05	30
Comments: Broke at 3" - bores enlarged corrosion and arcing at 39,element split.													
Comments:													
Comments:													
Comments:													
Comments:													
Comments:													

(CRD) Y-12 ELEMENTS (U)

Batch No.	Element S/N	Test				Test Parameters			Test Results				
									ΔW(g)	Corrected ΔW (g)			BAR (%)
		No.	Desig.	Aim (Min.)	Duration (Min.)	Temp. at 48.6" (°C)	Power (K.W.)	H ₂ Flow S.C.F./min.		Pinholes			
										0-35	35-52	0-52	
5442	431-1042251	1.b 1.1978	A6.02	30+30	30+12.3+ 17.7	2385/2345 2370/2340	899/890 878/875	590	16.2 9.7	3.79 -	6.01 -	9.80 1	0
Comments: Abort 12.3 chuck failure. BAR corroded up to 3/4" back.													
5442	431-1042254	1.b 1.989	A6.02	30+30	15.5	2370 2335	886 880	597	10.2 5.1	1.04 -	7.62 -	8.66 -	100
Comments: Surface corrosion 25 - 50" - corroded through 48-3/4".													
5442	431-1042277	1.b 1.1997	R1.02	20+20+20	20+15.3	2415 2375	1224 1193	863	5.2 5.0	0.72 -	2.33 -	3.05 3	95
Comments: Pre-bar of 95 - Abort loss of ΔP hole at 48-3/4".													
5442	431-1042282	1.b 1.2035	R1.02	20+20+20	20+20+20	2400/2375 2415/2395 2405/2380	1204/1192 1206/1195 1195/1186	865	16.0 9.5	3.92 -	5.26 -	9.18 -	15
Comments: Severe arcing 48-3/4 - 49-1/4 - BAR corroded up to 7/8" back.													
5443	431-1042223	1.b 1.1979	A6.02	30+30	8	2350	888	587	8.3 8.3	0.60 -	5.99 -	6.59 -	100
Comments: Abort, loss of ΔP. Broke at 48 coming down from power.													
5443	431-1042252	1.b 1.1988	A6.02	30+30	9.2	2350	887	593	8.0 7.4	N/A -	N/A -	N/A -	99
Comments: Broke at 49-1/4 corrosion pocket - Broke at 6-1/8 unloading, mechanical.													

~~(S)~~ Y-12 ELEMENTS (U)

Batch No.	Element S/N	Test				Test Parameters			Test Results				
									$\Delta W(g)$	Corrected $\Delta W(g)$			BAR (%)
		No.	Desig.	Aim (Min.)	Duration (Min.)	Temp. at 48.6"($^{\circ}C$)	Power (K.W.)	H ₂ Flow S.C.F./min.		Pinholes			
										0-35	35-52	0-52	
5444	431-1042287	1.b 1.1987	A6.02	30+30	30+30	2380/2370 2395/2370	832/823 831/825	593	$\frac{5.0}{4.6}$	0.72 -	1.44 -	2.16 1	100
Comments: Surface corrosion - 48 - 49-1/4.													
5444	431-1042260	1.b 1.1996	R1.02	20+20+20	20+20+20	2250/2250 2250/2230 2250/2250	1100/1082 1125/1020 1180/1142	871	6.0	2.58 -	1.27 -	3.27 -	80
Comments: Broke at 49 unloading - mechanical. BAR corroded up to 1/4" back.													
5444	431-1042326	1.b 1.2013	FCE Check A6.02	30+30	30+30	2370/2345 2360/2345	895/886 895/890	605	$\frac{9.4}{8.0}$	1.35 -	4.81 -	6.16 -	92
Comments: OK													
5444	431-1042280	1.b 1.2036	R1.02	20+20+20	20+20+20	4780 $^{\circ}$ R	1226/1213 1235/1235 1250/1260	874	$\frac{11.5}{11.5}$	3.39 -	5.35 -	8.74 -	85
Comments: Broke at 4-1/2 and 49.													
$\frac{5452}{6451}$	431-1042312	1.b 1.2113	R1.02	20+20+20	0.6	-	-	-	1.8	- -	- -	- -	100
Comments: Cracked at 50-1/4 D, E, and F Flats.													
$\frac{5452}{6451}$	431-1042261 Honed	1.b 1.2114	R1.02	20+20+20	2.5	-	-	-	$\frac{4.0}{0.8}$	- -	- -	- -	100
Comments: Cracked at 49-3/4 - E Flat.													

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(CRB) Y-12 ELEMENTS (U)

Batch No.	Element S/N	Test				Test Parameters			Test Results				
									Corrected ΔW (g)	Pinholes			BAR (%)
		No.	Desig.	Aim (Min.)	Duration (Min.)	Temp. at 48.6" (°C)	Power (K.W.)	H ₂ Flow S.C.F./min.		0-35	35-52	0-52	
5452 6451	431-1042262 Honed	1.b 1.2124	A6.02	30+30	1.0	-	-	-	1.3 0.8	-	-	-	100
Comments: Abort 1.0 - Cold End Damaged - Channel 3 corroded at 2-1/2 to 4 inches.													
5452 6451	431-1042310	1.b 1.2127	A6.02	30+30	30+30	2385 2340	905 903	593 603	16.0 12.0	5.24 -	6.73 -	11.97 -	40
Comments: BAR Corroded up to 3/4" back.													
5453 6451	431-1042313 Honed	1.b 1.2115	R1.02	20+20+20	10.7	2370	1235	862	1.7 1.7	-	-	-	100
Comments: Broke at 50-1/4 unloading.													
5453 6451	431-1042297	1.b 1.2116	A6.02	30+30	30+30	2345	905	559	9.4 9.5	0.54 -	6.04 -	6.58 -	100
Comments: OK													
5453 6451	431-1042301 Honed	1.b 1.2125	A6.02	30+30	30	2360	923	594	5.9 5.8	0.14 -	3.64 -	3.78 1	99
Comments:													
5453 6451	431-1042278	1.b 1.2140	A6.02	30+30	13+17+30	2385 2375	913 910	597 595	15.5 12.3	0.34 -	11.18 -	11.52 3	65
Comments: Abort 13' chuck failure. BAK corroded up to 1/2" back.													

~~(S)~~ LASL CORROSION DATA (U)

Batch No.	Element S/N	Test				Test Parameters			Test Results				
									ΔW(g)	Corrected ΔW (g)			BAR (%)
		No.	Desig.	Aim (Min.)	Duration (Min.)	Temp. at 43" (°C)	Power (K.W.)	H ₂ Flow lb/hr.		Pinholes			
										0-35	35-52	0-50	
B3-173 B3-174 B3-175	431-1042237	-	IRBT	20+20	20+20	2225	915	205	8.56	2.83	7.01	8.56	100
Comments:													
B3-176 B3-177	431-1042272	-	IRBT	3x20	3x20	2060	830	205	14.69	8.27	6.42	14.69	-
Comments:													
B3-176 B3-177	431-1042298	-	IRBT	3x20	3x20	2225	915	205	14.13	7.36	6.77	14.13	-
Comments:													
B4-186 B4-187	431-1042249	2999	IRBT	20+20	20+16	2060	830	205	11.61	3.21	8.40	11.61	-
Comments:													
B4-186 B4-187	431-1042293	3000	IRBT	20+20	20+2	2225	915	205	7.18	1.29	5.89	7.18	-
Comments:													
B4-189 B4-190 B4-191	431-1042270	-	IRBT	3x20	3x20	2060	830	205	11.07	7.00	4.13	11.07	-
Comments:													

(CRD) LASL CORROSION DATA (U)

Batch No.	Element S/N	Test				Test Parameters			Test Results				
									ΔW(g)	Corrected ΔW (g)			BAR (%)
		No.	Desig.	Aim (Min.)	Duration (Min.)	Temp. at 43" (°C)	Power (K.W.)	H ₂ Flow lbs./hr.		Pinholes			
										0-35	35-52	0-50	
B5-178 B5-179 B5-180	431-1042291	IBRPT	-	20+20	20+20	2060	830	205	7.0	4.13	2.26	6.39	100
Comments: Good appearance.													
B5-178 B5-179 B5-180	431-1042292	IBRPT	-	20+20	20+20	2225	915	205	12.1	6.14	4.90	11.04	100
Comments: Good appearance.													
B5-181 B5-182 B5-183	431-1042243	IBRT	-	3x20	20+20+12	2060	830	205	10.25	7.29	2.96	10.25	-
Comments:													
B5-181 B5-182 B5-183	431-1042316	IBRT	-	3x20	20+20+12	2225	915	205	15.47	9.90	6.73	15.47	-
Comments:													
B3-173 B3-174 B3-175	431-1042306	IBRT	-	20+20	20+20	2060	830	205	5.73	2.69	3.30	5.99	-
Comments: Run 20 + 20													
B3-173 B3-174 B3-175	431-1042306	IBRT	-	20	20	2060	830	205	10.3	5.63	4.67	10.3	-
Comments: Same element as above with another 20 min. cycle.													

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APPENDIX D (~~CONFIDENTIAL~~)

AIR IMPEDANCE RESULTS (U)

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(CRD) AIR IMPEDANCE VALUES FOR WANL ELEMENTS (U)

	Batch No. <u>G-88</u>					Element S/N <u>431-1042224</u>							Test Type <u>R1.02</u>						
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1008	.1008	.1006	.1006	.1008	.1006	.1000	.1006	.1007	.1004	.1002	.0996	.1000	.0998	.0998	.1000	.0999	.0998	.1000
Post 30																			
Post 60	Not Available (No Standards)																		

	Batch No. <u>G-88</u>					Element S/N <u>431-1042226</u>							Test Type <u>R1.02</u>						
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1010	.1010	.1008	.1007	.1009	.1008	.1006	.1004	.1004	.1005	.0994	.1000	.1004	.0997	.0992	.0996	.0998	.0995	.0992
Post 30																			
Post 60	Not Available (No Standards)																		

	Batch No. <u>G-88</u>					Element S/N <u>431-1042255</u>							Test Type <u>A6.02</u>						
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1008	.1005	.1007	.1002	.1004	.1005	.1002	.1001	.1002	.1004	.1002	.0994	.0996	.0996	.1000	.1002	.0992	.0996	.0996
Post 30																			
Post 60	N/A																		

~~(C)~~ AIR IMPEDANCE VALUES FOR WANL ELEMENTS (U)

	Batch No. <u>G-88</u>						Element S/N <u>431-1042267</u>						Test Type <u>A6.02</u>						
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1009	.1009	.1010	.1006	.1004	.1005	.1004	.1008	.1010	.1006	.1001	.0999	.1002	.1000	.1008	.1009	.1004	.1002	.1006
Post 30																			
Post 60	.1010	.1012	N/A	.1012	N/A	.0992	.1010	N/A	N/A	N/A	.1010	.1004	N/A	N/A	N/A	N/A	.1010	.1008	.1014

	Batch No. <u>G-89</u>						Element S/N <u>431-1042269</u>						Test Type <u>R1.02</u>						
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.0994	.0998	.0996	.1002	.0993	.0993	.1000	.0997	.0956	.0965	.0984	.0979	.0998	.0967	.0974	.0980	.0978	.0979	.0979
Post 30																			
Post 60	.1002	.1005	.1001	.1008	.1000	.1002	.1007	.0977	.0965	.0975	.0996	.0986	N/A	.0982	.0986	.0993	.0995	.0991	.0996

	Batch No. <u>G-89</u>						Element S/N <u>431-1042295</u>						Test Type <u>R1.02</u>						
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1000	.1006	.1003	.1006	.1001	.1003	.1006	.0994	.0994	.0974	.0980	.0993	.0988	.1001	.1004	.1002	.0996	.1000	.0986
Post 30	.1006	.1012	.1010	*	.1009	*	*	.1002	.1000	.0934	.0933	.1002	.0998	*	*	*	*	*	.0998
Post 60																			

*Off-Scale

(GPD) AIR IMPEDANCE VALUES FOR WANL ELEMENTS (U)

	Batch No. <u>G-89</u>							Element S/N <u>431-1042294</u>					Test Type <u>A6.02</u>						
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1000	.1009	.1008	.1008	.1002	.1002	-	.0976	.0984	.1009	.0986	.0990	.1003	.1005	.1010	.1006	.0996	.1000	.0990
Post 30																			
Post 60	N/A																		

	Batch No. <u>G-89</u>							Element S/N <u>431-1042241</u>					Test Type <u>A6.02</u>						
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.0995	.0999	.0988	.0999	.0999	.0998	.0991	.0988	.0996	.0987	.0999	.0984	.0999	.0992	.0998	.0999	.0986	.0988	.0998
Post 30																			
Post 60	N/A																		

	Batch No. <u>G-89</u>							Element S/N <u>431-1042661</u>					Test Type <u>A6.02</u>						
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.0980	.0981	.0992	.0977	.0968	.0950	.0979	.0950	.0965	.0972	.0980	.0949	.0949	.0980	.0985	.0983	.0962	.0972	.0952
Post 30																			
Post 60	.0988	.0994	.0999	N/A	.0990	.0966	.0998	.0934	.0998	.1002	N/A	.0984	.0965	.1004	N/A	N/A	.0980	N/A	.0990

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(CONF) AIR IMPEDANCE VALUES FOR WANL ELEMENTS (U)

Ch. No.	Batch No. <u>G-90/B-210</u>							Element S/N <u>431-1042265</u>							Test Type <u>A6.02</u>				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.0996	.0991	.0994	.0990	.0993	.0994	.0988	.0998	.0996	.0996	.0994	.0990	.0996	.0988	.0986	.0984	.0983	.0982	.0982
Post 30																			
Post 60	.0999	.0997	.0999	.0992	.0998	.0989	.0999	.0999	.0999	.0998	.0999	.0987	.0999	.0999	.0999	.0998	.0999	.0999	.0998

Ch. No.	Batch No. <u>G-90/B-210</u>							Element S/N <u>431-1042662</u>							Test Type <u>A6.02</u>				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.0992	.0987	.0993	.0996	.0985	.0985	.0982	.0990	.0986	.0976	.0974	.0977	.0976	.0974	.0968	.0980	.0973	.0981	.0973
Post 30																			
Post 60	N/A	.1009	.1010	.1002	.1002	.1004	.1003	.1010	.1008	.1010	.1009	N/A	.1009	.1008	.1004	.1004	.1000	.1000	N/A

Ch. No.	Batch No. <u>G-90/B-210</u>							Element S/N <u>431-1042259</u>							Test Type <u>A6.02</u>				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1001	.0990	.1010	.0996	.1000	.1001	.0992	.0998	.0995	.0999	.0998	.1001	.0989	.0980	.0982	.1000	.0987	.0980	.0980
Post 30																			
Post 60	.1001	.0993	.0998	.0994	.0999	.1001	.0996	.1008	.0999	.1001	.1002	.0991	.0998	.0988	.0997	.1002	.1000	.0990	.0997

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~~CONFIDENTIAL~~ AIR IMPEDANCE VALUES FOR WANL ELEMENTS (U)

	Batch No. <u>B-212/B-213</u>							Element S/N <u>431-1042655</u>					Test Type <u>A6.02</u>						
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.0998	.0992	.0997	.0991	.0989	.0987	.0986	.0993	.0990	.0988	.0991	.0991	.0985	.0988	.0987	.0981	.0988	.0990	.0993
Post 30																			
Post 60	-	-	-	-	-	-	-	N/A	-	.1008	-	-	-	.1009	-	-	-	-	-

	Batch No. <u>B-212/B-213</u>							Element S/N <u>431-1042659</u>					Test Type <u>A6.02</u>						
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.0997	.0987	.0997	.0990	.0986	.0989	.0989	.0996	.0980	.0981	.0987	.0996	.0985	.0984	.0985	.0988	.0989	.0986	.0989
Post 30																			
Post 60																			N/A

	Batch No. <u>B-212/B-213</u>							Element S/N <u>431-1042227</u>					Test Type <u>A6.02</u>						
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1020	.1018	.1018	.1020	.1018	.1020	.1018	.1015	.1015	.1014	.1010	.1004	.1016	.1008	.1008	.1010	.1012	.1007	.1008
Post 30																			
Post 60																			

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(C) AIR IMPEDANCE VALUES FOR WANL ELEMENTS (U)

	Batch No. <u>B-212/B-213</u>							Element S/N <u>431-1042304</u>						Test Type <u>A6.02</u>					
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1018	.1019	.1016	.1016	.1014	.1014	.1014	.1018	.1017	.1020	.1020	.1021	.1017	.1018	.1020	.1022	.1018	.1018	.1008
Post 30																			
Post 60																			

	Batch No. _____							Element S/N _____						Test Type _____					
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC																			
Post 30																			
Post 60																			

	Batch No. _____						Element S/N _____						Test Type _____						
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC																			
Post 30																			
Post 60																			

~~(CONFIDENTIAL)~~ AIR IMPEDANCE VALUES FOR Y-12 ELEMENTS (U)

Batch No. 5442 Element S/N 431-1042251 Test Type A6.02

Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1042	.1040	.1039	.1037	.1033	.1033	.1034	.1032	.1030	.1031	.1032	.1020	.1033	.1033	.1029	.1032	.1039	.1040	.1034
Post 30																			
Post 60																			

Batch No. 5442 Element S/N 431-1042254 Test Type A6.02

Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1033	.1032	.1034	.1030	.1029	.1031	.1033	.1035	.1029	.1029	.1035	.1037	.1034	.1034	.1033	.1034	.1031	.1035	.1032
Post 30																			
Post 60																			

Batch No. 5442 Element S/N 431-1042277 Test Type R1.02

Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1035	.1036	.1040	.1031	.1032	.1035	.1036	.1039	.1031	.1030	.1032	.1036	.1034	.1034	.1032	.1031	.1044	.1038	.1034
Post 30																			
Post 60																			

(CRD) AIR IMPEDANCE VALUES FOR Y-12 ELEMENTS (U)

	Batch No. <u>5442</u>						Element S/N <u>431-1042282</u>						Test Type <u>R1.02</u>						
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1040	.1036	.1037	.1038	.1035	.1036	.1036	.1035	.1036	.1036	.1036	.1038	.1034	.1036	.1036	.1037	.1038	.1039	.1042
Post 30																			
Post 60																			

	Batch No. <u>5443</u>						Element S/N <u>431-1042223</u>						Test Type <u>A6.02</u>						
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1038	.1040	.1042	.1031	.1033	.1036	.1034	.1029	.1030	.1032	.1031	.1035	.1032	.1031	.1032	.1032	.1036	.1036	.1035
Post 30																			
Post 60																			

	Batch No. <u>5443</u>						Element S/N <u>431-1042252</u>						Test Type <u>A6.02</u>						
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1036	.1030	.1029	.1034	.1033	.1027	.1023	.1032	.1033	.1031	.1023	.1022	.1029	.1029	.1023	.1020	.1029	.1026	.1023
Post 30																			
Post 60																			

(ADD) AIR IMPEDANCE VALUES FOR Y-12 ELEMENTS (U)

Batch No. 5444 Element S/N 431-1042287 Test Type A6.02

Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1017	.1022	.1026	.1010	.1010	.1023	.1027	.1024	.1011	.1008	.1011	.1019	.1019	.1006	.1006	.1011	.1010	.1009	.1011
Post 30																			
Post 60																			

Batch No. 5444 Element S/N 431-1042260 Test Type R1.02

Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1030	.1026	.1021	.1023	.1022	.1016	.1015	.1017	.1016	.1014	.1013	.1012	.1015	.1016	.1012	.1012	.1020	.1023	.1016
Post 30																			
Post 60																			

Batch No. 5444 Element S/N 431-1042326 Test Type A6.02 FCE Check

Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1016	.1020	.1027	.1009	.1011	.1019	.1025	.1009	.1008	.1010	.1016	.1019	.1014	.1012	.1012	.1014	.1022	.1022	.1013
Post 30																			
Post 60																			

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~~(CRD)~~ AIR IMPEDANCE VALUES FOR Y-12 ELEMENTS (U)

	Batch No. <u>5444</u>							Element S/N <u>431-1042280</u>						Test Type <u>R1.02</u>					
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	.1013	.1016	.1027	.1005	.1003	.1007	.1012	.1011	.1011	.1010	.1013	.1017	.1013	.1013	.1009	.1008	.1015	.1012	.1009
Post 30																			
Post 60																			

	Batch No. <u>5452/6451</u>							Element S/N <u>431-1042312</u>						Test Type <u>R1.02</u>					
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	Off Scale																		
Post 30																			
Post 60	Off Scale																		

	Batch No. <u>5452/6451</u>							Element S/N <u>431-1042261(Honed)</u>							Test Type <u>R1.02</u>				
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC								Off Scale											
Post 30																			
Post 60								Off Scale											

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Excluded from automatic downgrading and declassification~~

(SFO) AIR IMPEDANCE VALUES FOR Y-12 ELEMENTS (U)

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Excluded from automatic downgrading and declassification~~

Batch No. <u>5452/6451</u> Element S/N <u>431-1042262 (Honed)</u> Test Type <u>A6.02</u>																			
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	Off Scale																		
Post 30																			
Post 60	Off Scale																		

Batch No. <u>5452/6451</u> Element S/N <u>431-1042310</u> Test Type <u>A6.02</u>																			
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	N/A																		
Post 30																			
Post 60	N/A																		

Batch No. <u>5453/6451</u> Element S/N <u>431-1042313 (Honed)</u> Test Type <u>R1.02</u>																			
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Post NbC	Off Scale																		
Post 30																			
Post 60	Off Scale																		

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

60

~~CONFIDENTIAL~~ AIR IMPEDANCE VALUES FOR Y-12 ELEMENTS (U)

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

	Batch No. <u>5453/6451</u>							Element S/N <u>431-1042297</u>						Test Type <u>A6.02</u>											
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19						
Post NbC								Off Scale																	
Post 30																									
Post 60								Off Scale																	

	Batch No. <u>5453/6451</u>							Element S/N <u>431-1042301 (Honed)</u>						Test Type <u>A6.02</u>											
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19						
Post NbC								Off Scale																	
Post 30																									
Post 60								Off Scale																	

	Batch No. <u>5453/6451</u>							Element S/N <u>431-1042278</u>						Test Type <u>A6.02</u>											
Ch. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19						
Post NbC								N/A																	
Post 30																									
Post 60								N/A																	

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