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WANL-TME-1636

June, 1967

Westinghouse Astronuclear Laboratory

NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW MEETING
HELD WITH SNPO AT WANL ON JUNE 8, 1967
(Title Unclassified)

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JUN 28 1967

Mr. J. L. Dooling
NERVA Subcontract Manager
Nuclear Rocket Operations
Department 7140
Aerojet-General Corporation
Post Office Box 15847
Sacramento, California 95813

Subject: WANL-TME-1636, "Notes of Monthly Development Test Program Review Meeting Held with SNPO at WANL on June 8, 1967" (Title Unclassified), dated June 1967

Dear Mr. Dooling:

Transmitted for your information are ten (10) copies of the subject report.

Respectfully,

ORIGINAL SIGNED BY
W. H. ARNOLD FOR
H. F. Faught
Program Manager
NERVA Nuclear Subsystem

EAD/jok
Enclosures - 10

cc: R. W. Schroeder, SNPO-C, w/3 enclosures
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NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW MEETING
HELD WITH SNPO AT WANL ON JUNE 8, 1967
(Title Unclassified)

Westinghouse Electric Corporation
Astronuclear Laboratory
P. O. Box 10864
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Classification cancelled for changed to
by authority of H.F.C. TIC, date SEP 12 1973
by

E. A. DeZubay, Manager
Thermo-Flow Laboratory

C. L. Meuche, Manager
Engineering Mechanics Laboratory

INFORMATION CATEGORY

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Authorized Classifier Date

Group I - Excluded From Automatic
Downgrading and Declassification.

SPECIAL REVIEW FINAL DETERMINATION	Reviewer	Class.	Date
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NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW
MEETING HELD WITH SNPO ON JUNE 8, 1967

Attendees:

E. A. DeZubay	WANL	C. L. Meuche	WANL
G. T. Downs	WANL	R. J. Muth	WANL
N. J. Ettenson	WANL	J. S. Olinger	WANL
H. J. Fix	WANL	M. J. Rieb	AGC
R. W. Gagne, Jr.	SNPO-C	W. J. Rowan	WANL
W. J. Havener	WANL	J. D. Thomson	WANL
G. A. Kalvin	SNPO-C	E. A. Watjen	WANL
I. E. Kanter	WANL		

The Monthly Development Test Program Review Meeting was held on June 8, 1967.

Lists of the tests performed and planned next period by the Thermo-Flow and Engineering Mechanics Laboratories were distributed to those in attendance. These schedules are shown in Tables I and II.

The individual tests were then discussed in the order shown.

TABLE I
THERMO-FLOW LABORATORY TEST SCHEDULE

PERFORMED THIS PERIOD

PLANNED NEXT PERIOD (June)

Tests for NRX-A6

TFL-1.a Single Cluster Tests

Test	Configuration	Min.
12d	NRX-A6 Exit Gas Thermocouple (38' a, b, c)	<u>19</u> 57
13a	NRX-A6 Exit Gas Thermocouple (reported last period)	24.5
13b	NRX-A6 Exit Gas Thermocouple	15.0
13c	NRX-A6 Exit Gas Thermocouple	15.2
		<u>54.7</u>
14a	Irregular Tungsten Cup, Modified Skirtless Block (adj. to LASL cluster)	0.7
14b	Same as 14a	25.5
14c	Same as 14b	34.1
		<u>60.3</u>
15a	LASL Cluster (composite pedestal and protection cup and LASL fuel elements)	25.3
15b	Same as 15a	28.3
		<u>53.6</u>

Conduct two additional cycles as developmental tests at higher temperatures.

No further cup tests - block to be tested with composite cup.

Additional 60 min. test on a second cluster.

Sixty min. test on composite cup.

TFL-2.a Filler Strip Model

Model TFL-2.a. 0002 tested:

1. Hot helium tests.
2. Cold hydrogen test.
3. Twenty-nine min. at power with hydrogen.
4. Model removed from furnace to determine condition prior to any additional testing.

Additional testing will be determined by visual and x-ray examination.

TABLE I (CONTINUED)

PERFORMED THIS PERIOD (May)	PLANNED NEXT PERIOD (June)										
TFL-2.a Filler Strip Model (con't) Model TFL-2.a.0003: Filler strip awaiting 1. Coating. 2. Parts procurement. TFL-3.e Nozzle Interface Seal - Completed Testing.	Coating completed on filler strips and core July 24, 1967. Receive seal segments and inner reflector. No activity.										
General Development TFL-1.b Single Element Tests - Ten (10) tests at high power levels for furnace evaluation using high void elements. Four (4) tests for hot end and cold end chuck evaluations.	Tests of A4, A5, and A6 elements at screening test conditions as per Phase I-4B. Additional tests of high void Phase I-B elements, Y-12 matrix coated at WEFF at four power and flow levels. <table> <tr> <th><u>Power (KW)</u></th><th><u>Flow (scfm)</u></th></tr> <tr> <td>1275</td><td>800</td></tr> <tr> <td>1275</td><td>850</td></tr> <tr> <td>1050</td><td>800</td></tr> <tr> <td>1050</td><td>850</td></tr> </table>	<u>Power (KW)</u>	<u>Flow (scfm)</u>	1275	800	1275	850	1050	800	1050	850
<u>Power (KW)</u>	<u>Flow (scfm)</u>										
1275	800										
1275	850										
1050	800										
1050	850										
TFL-5.b Interstitial Corrosion - Temperature Effect.	Continue testing.										
Facilities Water Injection System											

TABLE II
ENGINEERING MECHANICS TESTING

PERFORMED THIS PERIOD (May 1967)

PLANNED NEXT PERIOD (June 1967)

Tests for NRX-A6			
EML-A.3	Spring Retainer Cap Rivet Seal Test	EML-C.1	Complete Remaining Proof Tests
EML-C.1	Axial Support Components Test		
	Tungsten Cup Test		
	Composition Cup Tests		
	LASL Pedestal Tests		
EML-D.5	Lateral Support System Dynamic Tests	EML-D.5	Vibration Tests at Higher G Levels
EML-E.1	Filler Strip Dummy Orifice Tests		
EML-E.2	Friction Tests	EML-E.2	Friction Tests of Reactor Components
EML-E.4	A6 Periphery Axial Load Tests	EML-E.4	A6 Periphery Axial Load Tests
Tests for NR-1			
EML-A.4	Ganged Drum Drive Band Tensile Tests	EML-A.4	Fatigue Test on Bands
EML-E.1	Core Periphery Wrapper Tests		
General Development			
EML-A.2	Beryllium Reflector Properties	EML-A.2	Strain Cycling Test on A6 Material
EML-E.3	Aft End Seal Tests	EML-E.3	Close Tolerance Element Core
Facilities			
Anti-Criticality Poison System Rig			

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TESTS FOR NRX-A6

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TFL-1.a Single Cluster Development Tests

A report on the last eight single cluster development tests was given during the meeting. Test TFL-1.a.0012d, an exit gas thermocouple test, was the final cycle on this assembly. It now has a cumulative time of approximately 57 minutes at a nominal 4300°R exit gas temperature. The thermocouple and supporting hardware were undamaged by the test. The thermocouple readings were lower than anticipated, based on measured power levels and mixed mean gas temperatures. The thermocouple has been turned over to the Instrumentation and Controls Department for evaluation. Tests TFL-1.a.0013b and TFL-1.a.0013c, which were also exit gas thermocouple tests, were operated for periods of 15 and 15.2 minutes respectively. During the first test the thermocouple quit reading after five minutes but the test was continued for the full 15 minutes at 4300°R exit gas temperature and then shut down normally. It was found that the molybdenum struts had melted and had fused onto the protective cup. The second test was conducted using the same thermocouple and supporting hardware including the protective cup (Figure 1). The test operated for a period of 15.2 minutes at 4300°R exit gas temperature. The test was shutdown suddenly when a fuel element failed, causing the temperature of the tie rod to rise, which kicked out the breaker. This assembly now has a cumulative time of 54.7 minutes at 4300°R exit gas temperature. The assembly is being held for further testing. It is planned to conduct two additional developmental tests on the NRX-A6 exit gas thermocouple at higher temperatures.

Test TFL-1.a.0014 was a 60 minute endurance test of the modified NRX-A6 block and irregular tungsten cup. The test was conducted in three cycles: a, b, and c. The total cumulative time for the assembly is 60.3 minutes at 4300°R. Preliminary post-test examination revealed some surface cracking of the tungsten, probably due to carbide formation; however, there were no deep cracks. The support block was corroded severely on one lobe as a direct result of coating loss, Figure 2. It was concluded that the configuration performed adequately under

FIGURE 1

SUPPORT HARDWARE AFTER 60 MINUTES ABOVE 4100°R (TFL-1.a.0013)

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FIGURE 2

MODIFIED BLOCK AND RELATED COMPONENTS AFTER
67.7 MINUTES AT 4300°R (TFL-1.a.0014c)

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design conditions for the required 60 minutes. There are no more tungsten cup tests planned but it is planned to test another support block with a composite cup in the near future.

Test TFL-1. a. 0015 was a single cluster development test using a LASL cluster, pedestal, and protection cup. The test was conducted in two cycles for a cumulative time of 53.6 minutes at a temperature of 4300°R. Both of the cycles were terminated because of external element corrosion due to coating chips. The second cycle was terminated by a very rapid shut-down subjecting the assembly to high thermal gradients. The assembly performed adequately with no apparent damage other than severe corrosion on the insulating cup. A microscopic post-test examination; however, revealed cracks in the counterbore seat area of the protection cup, Figure 3. As these cracks were so minute and not visually visible, it is not known if the cup was broken prior to or during the test. The next required test in this area is a 60 minute test on a composite cup.

TFL-2. a Filler Strip Corrosion Tests

Assembly of the filler strip test model, of the multi-layer wrapped periphery for NRX-A6, was completed during the period. The model was checked out with hydrogen at off power and helium at intermediate power levels. The data obtained from the check-out was used to establish nominal operating test conditions for the hot hydrogen test. A second hot helium test was conducted to determine what influence heater cavity flow would have on intermediate temperature levels. Test TFL-2. a. 0002, a hot hydrogen test, was conducted and operated for a period of 29 minutes before heater element failure terminated the test. While preparing to replace the heater, abnormal damage to the aft end heater support plug was noted. The test model is presently being removed from the furnace to further inspect the damage. Additional testing will be determined after the inspection of the model is completed.

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FIGURE 3
CRACK IN COUNTERBORE OF LASL COMPOSITE CUP (TFL-1.d.0015b)

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The test model for TFL-2, a. 0003 is progressing and the ordering of the material has been completed but not received. The filler strips have been received and are awaiting coating. Coating is scheduled to be completed July 24, 1967. The test will probably be conducted some time in August.

TFL-3. e Nozzle Interface Seal Performance Tests

Two of the NRX-A6 nozzle interface seals were successfully tested. Figure 4 shows a cross section of the test model. The data shows that there is a tendency for the leakage flow to decrease as the pressure differential increases, Figures 5 and 6. These figures also show a difference in the hysteresis of the two seals. This was caused by the one seal not sealing properly at the start-up of the test and suddenly snapping into place; thus, increasing the pressure differential from 40 to 520 psid. Other than this, the test was continued in a normal manner without further problems and no observable impairment of seal performance. Visual inspection of the seal, after completion of the test, showed the seal to be normal. The leakage was on the same order of magnitude as obtained for the omega type seals in previous reactors. There is no future activity planned in this area.

FIGURE 4
NOZZLE INTERFACE SEAL MODEL

FIGURE 5

A6 NOZZLE INTERFACE SEAL SER. NO. A58839 LEAKAGE EXPRESSED
AS A FUNCTION OF THE PRODUCT OF INLET DENSITY AND LEAKAGE DIFFERENTIAL

FIGURE 6

A6 NOZZLE INTERFACE SEAL SER. NO. A58840 LEAKAGE EXPRESSED
 AS A FUNCTION OF THE PRODUCT OF INLET DENSITY AND PRESSURE DIFFERENTIAL

EML-A.3 SPRING RETAINER CAP RIVET SEAL TEST

A series of tests were conducted to determine if an inspection hole of approximately 0.190 inch diameter in the A6 spring retainer cap, could be closed and sealed with a blind rivet. A series of discs with a web section duplicating that of the spring cap, were fabricated to test the blind rivet under a 200 psid pressure gradient. The disc rivet assembly was tested in a helium atmosphere at 535°R and 140°R temperatures.

The discs (Figure 7) were fabricated from 2027-T4 aluminum with a 1.125 diameter web and web thicknesses of 0.052 to 0.100 inches.

The web was machined in the same manner as the A6 spring retainer cap, 928F829, to insure simulation of reactor hardware. Prior to testing, all parts were cleaned with an ultra-sonic cleaner and then grain alcohol.

Three types of holes to accommodate the rivet were tested :

1. Standard No. 11 (.1910 dia.) hole
 No specification for R & F
2. $.193 \begin{smallmatrix} + .000 \\ - .005 \end{smallmatrix}$ diameter hole
 R = .005 max. and F = 16 RMS
3. $.193 \begin{smallmatrix} + .000 \\ - .005 \end{smallmatrix}$ diameter hole with
 R = .015 - .025 and F = 16 RMS

Three types of domed head, closed end blind rivets of Type 1100 aluminum with .187dia., shank and Type 7178 aluminum mandrel were used.

1. .450 inch shank length
 32 - 63 RMS finish (unpolished)
2. .325 inch shank length
 32 - 63 RMS finish (unpolished)

FIGURE 7
Section of 2024-T4 Aluminum Disc
For Blind Rivet Testing
EML-A.3

3. .325 inch shank length
16 RMS finish (polished)

Figure 8 shows two types of short rivets, a disc and the low pressure side of the assembled configuration. Two stainless steel O-rings were used to seal the disc while under pressure in the fixture. After 41 tests, two configurations yielded satisfactory results. All eleven tests of a type "3" hole and the short, unpolished rivet did not leak under ambient and cryogenic conditions. Two of the ten tests with type "3" hole and the short polished rivet produced insignificant leaks under cryogenic conditions.

The .193 diameter hole with a radius of .015 - .025 inches and a 16 RMS finish produced fewer leaks than any other hole configuration tested. While use of an unpolished rivet produced a no leak seal in all tests conducted, a group of poorly manufactured rivets could result in many poor seals if shank surface finish varied widely. Polishing eliminates this variable and it was decided that a polished, short blind rivet would be used with the optimum hole indicated above for NRX-A6.

EML-C.1 Axial Support Component Tests

During the month proof tests were conducted on the three types of support hardware to be used in the A6 reactor. Irregular tungsten cups, carbide composition cups (H section) of LASL and Carborundum Co. material, and carbide composition pedestals and cups of LASL manufacture and design were subjected to the following tests:

- 1) Creep - the specimen is brought up to 4300°R with a small load and then loaded for one hour at full load. During cooldown only a small load is applied.

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FIGURE 8
Blind Rivet Disc Test Assembly
EML-A.3

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- 2) Crack Initiation - the specimen is loaded at room temperature and held while the temperature is raised to 4300°R for ten minutes and then cooled with the load still held at the same level.
- 3) Room Temperature - the specimen is loaded in incremental amounts to failure or maximum specified loading with microscopic examination between loadings.

Tungsten Cups

Figure 9 shows a tungsten cup and the associated components which are used in all proof tests; an ATJ support washer is under the lower or smaller cup assembly, and loads are applied to the tie rod button head shown atop the moly cone on the right .

The first test of the A6 proof hardware was a creep test at 4300°R with a load of 1100 lb for one hour. The second test was a room temperature test with loadings to begin at 1100 lb. During this test a dropoff in load was noticed at 400 lb and upon inspection a crack was found in the fillet radius of the smaller cup. A post test inspection of the creep test specimen previously tested did not reveal any cracks, however, after sectioning cracks appeared in two places through the web as shown in Figure 10. The specimen was resectioned so that the length of the crack might be observed and the other half of the sectioned specimen was polished but no cracks could be found on either the repolished or resectioned specimens. Therefore, it was concluded that the cracks resulted from improper polishing or sectioning operations. Subsequent investigations of the room temperature specimen showed that the parts had been conditionally accepted after dye-penetrant inspection had revealed indications of cracks in the radius of the smaller cup.

FIGURE 9
IRREGULAR TUNGSTEN CUP HARDWARE
EML-C.1

FIGURE 10

SECTIONED VIEW OF TUNGSTEN CUPS "CRACKED" DURING THE FIRST CREEP TEST
SUBSEQUENT INVESTIGATION REVEALED THAT CRACKS DID NOT EXIST
IN THE OPPOSITE HALF AND DID NOT PROGRESS ALONG THE FACE.

EML-C.1

The room temperature test was repeated on two new assemblies and no cracks appeared in either cup after testing as high as 3300 lb on the one specimen and 4050 lb on the second specimen. One of the cups was then taken to an ultimate load of 4120 lb when radial cracks developed in the large cup. An additional creep test was also run under identical conditions to the first test with no cracks appearing during sectioning and metallography. Two additional cups were given crack initiation tests at 4300°R with loadings beginning at 1100 lb and the tests were discontinued when no cracks were found after testing as high as 1500 lb.

Composite Cups

Composite cups made from billets of LASL material were also tested during the last period. Figure 11 shows the design hardware for the H-cross section composite cup with the water cooled load rod used to apply mechanical loads to the tie rod button and moly cone.

Three tests were completed during this period. One was a creep test in which the cup was loaded to 1100 lb. at 4300°R for one hour. No measurable creep deformation or other damage was found in the specimen. A second cup was tested in a crack initiation test at 4300°R under sequential loads of 900 lb, 1100 lb and 1300 lb. No damage was found in this specimen which confirmed previous findings during the development program when similar cups with pyrofoil washers had been tested as high as 1800 lb without cracking. A third cup was tested at room temperature to a load of 2500 lb when the cup shattered after contact was made with the support block.

A single cup of Carborundum material became available during this period and it was creep tested under an 800 lb load and a temperature of 4300°R

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FIGURE 11 NRX-A6 REGULAR BLOCK COMPONENTS

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for one hour with no distortion or cracking noted. This test was not a proof test.

LASL Pedestals

Tests of the LASL pedestal design and protection cup were conducted with identical techniques and fixturing as used on WANL designed cups. A photo of the LASL pedestal and cup assembly is shown in Figure 12 with a moly cone installed in position. During all our tests loads were applied to the tie rod button with all reactor hardware in position. Furnace tests were conducted using fueled LASL elements in a shortened cluster configuration as shown in Figure 13. In all room temperature testing the specimens were loaded against a graphite surface. In addition to the mechanical tests, four sets of pedestal and cup assemblies were welded together for use in the Fluid Flow and other laboratory tests. The cups were welded under conditions prescribed by LASL by loading to 1000 psi (500 lb) at a temperature of 5400°R for ten minutes.

The first test completed on a LASL pedestal assembly was a creep test at 900 lb, 4300°R for one hour. Upon completion of this test no cracks were found in any of the components, however, during sectioning it was found that circumferential cracks were present in the fillet radius of the protection cup. Additional crack initiation and room temperature tests were run to confirm these results. These showed that cracks developed in the cup radius between 500 and 900 lb. A single pyro-foil washer was introduced between the insulating cup and protection cup and the assembly was tested under the standard crack initiation test beginning with loadings at 500 lb. The 500 lb loading produced no damage but the 900 lb loading resulted in the same type of crack in the fillet radius.

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FIGURE 12
LASL PEDESTAL SUPPORT

EML-C.1

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FIGURE 13
LASL PEDESTAL AND CUP

EML-C.1

In another test two pyrofoil washers were used between the insulating cup and protection cup and the assembly passed the crack initiation test at 500 lb, 700 lb, 900 lb and 1100 lb.

A thermal shock test was conducted at the Los Alamos Scientific Laboratory in the single element test facility using a pre-welded cup and pedestal assembly at a nominal temperature of 4300°R and a flow of 140 lb/hr hydrogen flow. In this test the pedestal assembly was held in place by a gas controlled holding fixture. Gas flow was held steady while the temperature of the gas was ramped upwards at a desired rate. Two temperature ramps were completed, one at a nominal 50°/sec and the other at a nominal 100°/sec. While the temperature was changing, an attempt was made to vary the loading on the cup by changing the gas pressure on the holding fixture. This was to simulate varying flow forces calculated for the reactor. Upon completion of the 100°/sec ramp a crack was found in the radius of the protection cup similar to those observed during crack initiation tests at the Engineering Mechanics Laboratory and the cluster test conducted at the Thermo-Flow Laboratory. Data from this thermal shock test is being reduced.

EML-D.5 Dynamic Test of Partial Core (EML-86)

The functional dynamic tests were completed on the Partial Length Assembly. The test setup is seen in Figure 14. The core was supported by a fixture which was allowed to pivot about a point 52 inches forward of the aft end of the core. The core and core support fixture were suspended inside the reflector support fixture on the pivot pin as shown in Figure 15. Two thrusters were used to apply radial loads to the assembly and outputs from accelerometers and three NRX-A6 displacement transducers were recorded on oscillographs and tape. The NRX-A6 transducers were used to

FIGURE 14
TEST SETUP FOR LATERAL VIBRATION
TEST OF SUPPORT SYSTEM
EML-D.5

FIGURE 15
PIVOT ARRANGEMENT
EML-D.5

measure the relative motions between the core and outer reflector with the arrangement as shown in Figure 16. Location of some of the more important sensors are sketched in Figure 17.

A summary of dwell and sweep tests is given in Table III. The total cycles and pertinent comments are also noted in the table.

Figure 18 shows the fixture resonances which limited the sweep tests above 100 cps to acceleration levels of 1 g. A 2 g sweep was run below 100 cps and is plotted in Figure 19. Dwells at 150, 225, 295, 405 and 500 cps were also run to acceleration levels of 2 g.

A disassembly of the core and lateral support system showed no damage had resulted from the dynamic test. Breakaway, defined as relative motion between reflector and core of 15 mils, was not in evidence.

At the conclusions of the reported tests, an evaluation of assembly procedures was made jointly by personnel from Reactor Assembly, Reactor Design and Engineering Mechanics. The graphite core was replaced with a plastic cylinder which enabled a visual inspection of the inner seal segments and pins. Certain exaggerated misalignments in the positioning of the inner seal segments were evaluated. This investigation, demonstrated that the procedures and inspections to be used for the NRX-A6 reactor assembly will assure that the pins and seals positioned correctly.

EML-E.1 Filler Strip Dummy Orifice Test

The original filler strip design of the NRX-A6 included coolant channels with orifices. Recent changes in the periphery eliminating the coolant flow made it necessary to plug these holes in the filler strips. The modified design consists of dummy orifices at the cold end with graphite rods running axially through the hole and retained at the hot end by a

FIGURE 16
NRX-A6 DISPLACEMENT TRANSDUCER -
LATERAL VIBRATION TEST OF CORE SUPPORT SYSTEM
EML-D:5

SCHEMATIC OF TEST SET UP

FIGURE 17
EML-D.5

FIGURE 18
 1 "G" SWEEP TEST SUMMARY
 EML-D.5

FIGURE 19
 2 "G" SWEEP TEST SUMMARY
 EML-D.5

TABLE III VIBRATION TEST OF PARTIAL LENGTH LATERAL SUPPORT SYSTEM

Type of Test	Frequency cps		Control Level		Number of Cycles (Thousands)	Comments
	Start	End	g (S.P.)	Displacement inch (P to P)		
Sweep	500	10	1/4	---	58	
Sweep	500	9	1/2	---	73	
	9	7	---	0.12		
Sweep	500	12	1	---	69	Fixture resonance noted at 127, 250, 400.
	12	7	---	0.12		
Sweep	100	16	1.5	---	18	Investigation limited to frequency below fixture resonances.
	16	7	---	0.12		
Sweep	87	19	2.0	---	29	Investigation limited to frequency below fixture resonance.
	19	7	---	-/12		
Sweep	80	95	2.0	---	11	Started to investigate frequencies above 100 cps but displacement transducer showed output. (Vibration test of transducer is planned)
Dwell	150	150	1/4, 1/2, 1, 1-1/2, 2	---	11	Investigation at selected frequencies
	225	225	1/4, 1/2, 1, 1-1/2, 2	---	11	
	295	295	1/4, 1/2, 1, 1-1/2, 2	---	15	
	405	405	1/4, 1/2, 1, 1-1/2, 2	---	20	
	397	397	1/4, 1/2, 1	---	55	
	500	500	1, 1-1/2, 2	---	42	

transverse pin that was brazed into position. A special test was requested to evaluate the modification under a total of five thermal cycles under a reactor filler strip axial temperature profile with a temperature of 4300°R at the hot end. This test was run in the 6×54 furnace and the first cycle was completed such that the orifice end of the strips was permitted to reach 1600°R and the aft end about 4000°R . This resulted in a partial lifting of the dummy orifice. The filler strips were removed and the orifice recemented for the remaining test cycles and the temperature limits re-evaluated. During the remaining cycles the orifice end temperature was limited to 1000°R (the max. allowable temperature during engine operation) with the aft end at 4300°R . No changes were noted other than discoloration of the cement during the remaining test cycles. The aft end plug remained in position and is presently being sectioned for further evaluation.

EML-E.2 Friction Tests of Reactor Components

Friction tests using pyrofoil as a sliding interface between uncoated filler strips on NbC coated fueled elements and NbC coated unfueled partial elements were performed in hydrogen at 4400°R and 35 psi contact pressure. These tests were conducted to determine the effect on friction of various materials proposed as temporary pyrofoil attachment mediums which could be used to facilitate reactor assembly.

One layer of 0.003 inch pyrofoil was attached to the uncoated filler strip specimen to form an interface between the uncoated and NbC coated surface. Dow Corning High Vacuum grease and commercial grade paraffin were used as the attaching mediums. The Dow Corning High Vacuum Grease was applied to the filler strip specimen in a thin uniform coating. The filler strip specimen was positioned on the pyrofoil, and with a

slight circular motion was pressed on the pyrofoil. The attachment using paraffin was made by heating the filler strip and pyrofoil specimens to approximately 200°F, and applying just enough paraffin to wet the pyrofoil surface. The warm filler strip specimen was held in contact with the foil until the paraffin solidified. Four tests were conducted using paraffin and four tests were conducted using Dow Corning High Vacuum grease.

Significant "stick-slip" occurred during the initial motion of the first cycle when the Dow Corning High Vacuum grease was used. No appreciable "stick-slip" was evident on subsequent cycles. Post-test examination of the specimens revealed that when the Dow Corning High Vacuum grease was used, particles of pyrofoil adhered to the filler strip specimens. Test conditions and results are summarized in Table IV. These show that a commercial grade of paraffin is a satisfactory temporary bonding material from a friction effect standpoint and can be used in the NRX-A6 assembly.

EML-E.4 A6 Core Periphery Axial Load Tests (EML-94)

Testing is in progress to determine the strength of filler strip keyways. The test simulates the transmission of axial loads from fuel elements and partial element keys to these keyways. The following results are available:

<u>Filler Strip Position</u>	<u>Serial Number</u>	<u>Axial Failure Load (lbs)</u>
19	A91782	218
	A91866	198
	A91882	202
11	A91204	121

These data compare favorably to the calculated strength as determined by Reactor Design.

TABLE IV

Specimens	No. of Cycles	Static Coefficient of Friction	Results
0.003 pyrofoil between the graphitite "G" filler strip and NbC coated fueled element specimen. Pyrofoil bonded with silicone grease to graphitite "G" filler strip	4	(After 10 minute soak at 4400°R temperature) 0.21	On initial motion cycle at approximately 3300°R friction was approximately 1.08
0.003 pyrofoil between the graphitite "G" filler strip and NbC coated fueled element specimen. Pyrofoil bonded with silicone grease to graphitite "G" filler strip	4	0.22	On initial motion cycle at approximately 3650°R friction was approximately 0.74
0.003 pyrofoil between the graphitite "G" filler strip and NbC coated fueled element specimen. Pyrofoil bonded with paraffin to graphitite "G" filler strip	4	0.23	On initial motion cycle at approximately 2250°R friction was approximately 0.19
0.003 pyrofoil between the graphitite "G" filler strip and NbC coated fueled element specimen. Pyrofoil bonded with paraffin to graphitite "G" filler strip	4	0.26	On initial motion cycle at approximately 3550°R friction was approximately 0.27

Specimens	No. of Cycles	Static Coefficient of Friction	Results
0.003 pyrofoil between the graphitite "G" filler strip and NbC coated unfueled partial element specimen. Pyrofoil bonded with silicone grease to graphitite "G" filler strip	3	(after 10 minute soak at 4400°R temperature) 0.29	On initial motion cycle at approximately 3500°R friction was approximately 1.28
0.003 pyrofoil between the graphitite "G" filler strip and NbC coated unfueled partial element specimen. Pyrofoil bonded with silicone grease to graphitite "G" filler strip	3	0.47	On initial motion cycle at approximately 3650°R friction was approximately 0.70
0.003 pyrofoil between the graphitite "G" filler strip and NbC coated unfueled partial element specimen. Pyrofoil bonded with paraffin to graphitite "G" filler strip	5	0.32	On initial motion cycle at approximately 3000°R friction was approximately 0.28
0.003 pyrofoil between the graphitite "G" filler strip and NbC coated unfueled partial element specimen. Pyrofoil bonded with paraffin to graphitite "G" filler strip.	5	0.24	On initial motion cycle at approximately 2250°R friction was approximately 0.17 and at 4250°R friction was 0.19

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TESTS FOR NR-1

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EML-A.4 Ganged Drive System

Two band tensile test specimens were tested at -320°F . These specimens were made of titanium per PDS 30067-1 (5% Al, 2-1/2% Sn) and have a gage length of 4.00 inches and a cross-section dimension of 0.750 by .010 inches. A typical specimen which failed at -320°F is shown in Figure 20 .

Test data are shown below:

<u>Specimen</u>	<u>Youngs Modulus, E psi</u>	<u>.2% Yield Strength, psi</u>
1	17.8×10^6	168,000
2	17.6×10^6	182,000

This information is required to establish band pre-load and stress for the forthcoming band tensile-fatigue tests.

Existing material property data are not valid for specimens in the thickness range being considered for the ganged drum drive bands.

EML-E.1 Core Periphery Wrapper Tests

One of the candidate designs for the NR periphery uses ten layers of 0.0055 inch pyrofoil fitted to the core outer diameter between the elements and filler strips. This arrangement is shown in Figure 21 as installed in the EML-68 test fixture. The filler strips used in this test were machined to take up the differences due to the thickness of the stacked foils. The foil was fitted by hand to the configuration of the elements in the assembly. The primary objectives of the test were to see if the foil could be installed in this fashion and to observe the effects of temperature and pressure cycles on the configuration. The assembly was tested at a maximum temperature of

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FIGURE 20
EML-A.4

A TYPICAL TITANIUM BAND SPECIMEN
AFTER TENSILE FAILURE AT -320°F

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FIGURE 21
A6 FILLER STRIPS
EML-E.1

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4200°R and a differential pressure across the foil of 46 psid. Temperature measurements on either side of the foil indicated a difference of 600°R.

Figure 22 shows the pyrofoil assembly after removal from the test rig upon completion of the temperature test. The results show that:

- 1) wrapper integrity was maintained under the irregularities of the core outer diameter and,
- 2) the filler strip wrapper assembly functioned properly and appeared to maintain a leak-tight wrapper,
- 3) for assembly purposes the pyrofoil could be pre-formed prior to assembly for ease of installation.

FIGURE 22
PYROFOIL ASSEMBLY AFTER REMOVAL
FROM TEST RIG
EML-E.1

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GENERAL DEVELOPMENT

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TFL-1. b Single Element Process Development and Evaluation Tests

There were 14 single element experiments conducted at WANL during this period. Ten tests were furnace engineering evaluations, at high power and flow levels, using high void elements. Six of these were operated at 4900°R at the 48.6 inch port, one was operated at 4800°R at the 46.8 inch port, and three were operated at 4500°R at the 37.6 inch port. The furnace performed very well throughout the tests. The fuel element tests averaged eight minutes each with a nominal weight loss of 10 grams.

Of the other four tests conducted, one was operated to evaluate a longer cold end chuck with a stainless steel insert. The chuck performed very well. Another test was conducted to evaluate a multi-fingered hot end chuck. This chuck also performed very well. The final two tests were conducted to evaluate a blunt nosed hot end chuck, with decreased contact area, to determine if the hot end behavior of the fuel element would be improved, if current did not pass through the tip joint. The first test indicated no arcing or melting of coating on the hot end of the fuel element in the chuck contact area. In the second test, corrosion occurred in the chuck area apparently due to defects in back coating on the fuel element. Additional hot end chuck evaluation tests are planned. It is also planned to test NRX-A4, A5, and A6 fuel elements at screening test conditions as per Phase I-4B and additional tests of high void Phase IB fuel elements and fuel elements of Y-12 matrix which will be coated at WEFF. They will be tested at four different power and flow levels.

TFL-5. b Interstitial Corrosion Tests

Two tests studying the effects of temperature change on the corrosion reaction in narrow slots were conducted in this report period. The test conditions and results are given as follows:

Test Number (TFL-5. b.)	041	042
Test Time (min)	15	15
Inlet Pressure (psig)	200	200
Inlet Gas Temperature ($^{\circ}$ R)	528	534
Average Material Temperature ($^{\circ}$ R)	3724	3499
Flow Rate (lb/sec- H_2)	4.28×10^{-5}	4.30×10^{-5}
Weight Loss (gms)	0.405	0.367
Weight Loss Rate (gms/min)	0.027	0.0244
Corrosion Rate (gms/in ² -sec)	1.113×10^{-4}	1.02×10^{-4}

The data obtained for 3700 $^{\circ}$ R was not in line with the value predicted from previously obtained data. Examination of the operating curves of the test furnace has confirmed that the conditions as stated are correct and the reduction in corrosion rate is expected because of the conditions of chemical boundary layer, pore diffusion, and equilibrium concentration.

The second set of data is a retest of the 3500 $^{\circ}$ R point. The original point used was data taken from the pressure effect series and was based on a 30 minute rather than a 15 minute test time. The corrosion rate used was re-evaluated on the basis of 15 minutes of operation. The test was conducted to confirm the data that has been obtained to date and to check the results of the data at the 3700 $^{\circ}$ R temperature level. The results of these tests along with the previously obtained data is shown in Figure 23.

FIGURE 23
 LOG OF WEIGHT LOSS RATE AS A FUNCTION OF THE
 RECIPROCAL OF MATERIAL TEMPERATURE

EML-A.2 Beryllium Reflector Properties

Five low cycle fatigue tests at 140°R were completed on 0.75 inch diameter specimens machined from block pressing no. 3824. The strain-cycle data from these tests along with two monotonic test results are shown below.

BERYLLIUM STRAIN/CYCLE DATA AT 140°R

<u>Test No.</u>	<u>Cycle Mode</u>	<u>Strain Range - %</u>		<u>Cycles to Fracture</u>	<u>Stress at Fracture-psi</u>
		<u>Total</u>	<u>Plastic (*)</u>		
UN-1	Monotonic	+0.270	+ 0.180	1/4	36,000
UN-8	Monotonic	+0.232	+ 0.154	1/4	35,000
UN-4	Comp./Tension	0.391 ^{-0.237} _{+0.154}	0.287	3/4	35,000
UN-5	Comp./Tension	0.24 ± 0.12	0.067 ± 0.0335	18	35,000
UN-6	Comp./Tension	0.30	0.095	51	39,600
UN-7	Comp./Tension	0.30	0.087	150	46,000
UN-9	Comp./Tension	0.30	0.096	66	45,000

* Plastic range taken from mid-life hysteresis loop

In general, the normal low cycle fatigue behavior of most materials in terms of plastic strain range (ΔE_p) and cycles to fracture (N_f) can be represented by a straight line with a slope of $-1/2$ on a log-log plot. The relationship as derived by Coffin is expressed mathematically as $N_f^{1/2} \Delta E_p = E_f/2$ where E_f is the fracture ductility.

Results of our present tests on beryllium would indicate that a straight line relationship with the same parameters exists but with somewhat different slope. Although more tests are required to establish the "scatter band" the

expression $N_f .182 \Delta E_p = .777 E_f$ seems to fit the experimental data well.

A comparison of Coffin's criteria and the curve obtained during the low cycle fatigue tests on beryllium is shown in Figure 24. A typical instrumented beryllium specimen is shown in Figure 25 , and a typical specimen after failure is shown in Figure 26 .

EML-NT-1 Aft End Seal Tests

Assembly of the 9-1/2 inch seven cluster model core with close tolerance elements is in progress. With the exception of the selected tighter tolerance elements this core duplicates the first sleeveless core and will provide a model for direct comparison with the sleeved core.

Two coated subassembly element samples were prepared with pyrofoil sleeves and refractory metal wrap at each end of the sleeve. These samples will be part of an evaluation study to determine if the edges of pyrofoil sleeve can be "sealed" at operating temperature by formulation of a refractory carbide. Due to difficulties in adapting our samples to the standard diffuser test furnace at WANHES several modifications to the holder and diffuser have to be made. The two initial samples prepared with zirconium and niobium wraps are scheduled to be run as soon as the modified holder is recoated.

FIGURE 24
 EML-A.2

FIGURE 25
EML-A.1
A BERYLLIUM SPECIMEN INSTRUMENTED
BEFORE TESTING

FIGURE 26
EML-A.1
A FAILED BERYLLIUM SPECIMEN

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Engineering Mechanics Laboratory Facilities

Anti-Criticality Poison System

The Poison Wire Test structure has been assembled and operated and test instrumentation is now being installed. The facility previously used for the control drum tests will be used to soak a cluster of elements at temperatures from ambient to -320°F . Instrumentation will allow drag loads on the poison wires to be recorded at various angles and speeds of withdrawal.

Thermo-Flow Laboratory Facility

The water injection system will be checked out this month.