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WANL-TME-1670

MASTER

Westinghouse Astronuclear Laboratory

NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW MEETING
HELD WITH SNPO AT WANL ON AUGUST 31, 1967

(Title Unclassified)

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**NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW MEETING
HELD WITH SNPO AT WANL ON AUGUST 31, 1967**

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by H.F.C. TIC, date SEP 12 1973

E. A. DeZubay

E. A. DeZubay, Manager
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NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW MEETING HELD WITH SNPO AT WANL ON AUGUST 31, 1967

Attendees:

E. A. DeZubay	WANL	H. Murphy	SNPO-C
H. J. Fix	WANL	R. J. Muth	WANL
R. Gagne	SNPO-C	J. S. Olinger	WANL
W. J. Havener	WANL	E. W. Pianka	WANL
I. Helms	SNPO-W	M. J. Rieb	AGC
G. A. Kalvin, Jr.	SNPO-C	W. J. Rowan	WANL
I. E. Kanter	WANL	L. A. Salvador	WANL
C. L. Meuche	WANL	F. G. Tauch	WANL

The Monthly Development Test Program Review Meeting was held on August 31, 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.

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TABLE I
THERMO-FLOW LABORATORY TEST SCHEDULE

PERFORMED THIS PERIOD (August)

PLANNED NEXT PERIOD (September)

Tests for NRX-A6

TFL-1. a Single Cluster Tests

Test Configuration

TFL-1. a. 17 LASL Cluster (with foil washers in cup)
3 cycles: Total test time 60.5 min.

TFL-1. a. 18 Exit Gas Thermocouple: Aborted

TFL-1. a. 19a Exit Gas Thermocouple at 4450°R
5.0 min.

TFL-1. a. 19b Exit Gas Thermocouple at 4600°R
5.1 min.

Data reduction, metallurgical examination,
and documentation of NRX-A6 tests.

TFL-2. a Filler Strip Model

Received test hardware and completed mock-up
assembly for TFL-2. a. 0003.

Installed anti-friction slip planes.

Continued analysis of TFL-2. a. 0002.

Preliminary heater design for TFL-2. a. 0003.

Complete assembly and test TFL-2. a. 0003.

Preliminary data analysis TFL-2. a. 0003.

General Development

TFL-1. b Single Element Tests

Total Tests - Thirty-Nine (39)

- 10 Phase I-3B
- 19 High Void - Phases II-Fa, II-A-2a, I-B, I-D
- 4 Chuck Development
- 1 Air Impedance Probe
- 3 NRX-A6 O. D.
- 2 NRX-A4, A5, A6 Comparisons

Tests of high void elements from Phase
II-A-2a and Phase I-D, LTRM coating of
high void elements. Methane injection
tests to determine inhibition of element
corrosion.

Tests for chuck development.

TABLE I (Continued)

PERFORMED THIS PERIOD (August)

PLANNED NEXT PERIOD (September)

General Development (Continued)

TFL-5.b Interstitial Corrosion - Pyrofoil Corrosion Tests

Continue Testing.

Facilities

5000 Gallon Dewar

Action Items

Air Impedance Gage.

Valves for Dual Furnace Operation at WANHES

TABLE II
ENGINEERING MECHANICS TESTING

Performed This Period

Planned Next Period

Tests for NRX-A6			
EML-D.1	Lateral Support Spring Relaxation Test		
EML-E.2	Particle Catcher Tests		
EML-E.4	Filler Strip Orifice Plug Radial Load Test Axial Load Tests on Filler Strips & Tiles Ultimate Strength Tests of Filler Tiles		
EML-C.4	Central Element Tension Tests		
EML-E.2	Adhesive Residue Evaluation	EML-E.2	Friction Tests of Foil Attachment
EML-G.1	Exit Gas T/C Vibration Test	EML-G.1	Complete Exit Gas T/C Vibration Test
		EML-B.2	XE-1 Element Support Tests
EML-B.3	Transportation Test of A6 Poison Rods	EML-B.3	Transportation Test of XE-1 Poison Rods
Tests for NR-1			
EML-B.3	Poison Wire Removal Tests	EML-B.3	Low Temperature Removal Tests
EML-C.1	Pedestal Thermal Shock Test	EML-C.1	Pedestal Creep and Thermal Shock Tests
EML E.1	Overlapped Wrapper Test	EML-E.1	Continue Wrapper Development Tests
EML-A.4	Band Fatigue Tests	EML-A.4	Band Fatigue Tests
General Development			
EML-A.2	Beryllium Reflector Properties	EML-A.2	Beryllium Reflector Properties
Facilities			
EML-E.2	Temperature Checkout of New Friction Furnace		
EML-H.1	XECF Resonant Survey		

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TESTS FOR NRX-A6

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TFL-1. a Single Cluster Development Tests

A single cluster test, TFL-1. a. 0017, employing a LASL cluster with a composite pedestal and protection cup, was conducted in three cycles for a total endurance time of 60.5 minutes. The test was conducted at a nominal steady-state temperature of 4350°R. Two large pyrofoil washers were employed between the insulating cup and the protection cup. The purpose of the washers was to prevent stress cracking in the counterbore area of the protection cup. Cracking in this area had been observed in cluster test TFL-1. a. 0015 which was previously described in WANL-TME-1636. There was very little corrosion observed at the completion of the test but there was a small crack in the cup. Metallographic inspection showed that the crack did not extend beyond the NbC coating.

(C-RD) Figure 1 shows the condition of the pedestal, cup, and washers after the final test cycle. Test TFL-1. a. 0018 was terminated during start-up because of a broken striker plate (entrance to heat exchanger). Test TFL-1. a. 0019, with an exit gas thermocouple assembly, was conducted in two 5 minute cycles. The assembly was tested at off design exit gas temperatures of 4450°R and 4600°R. The thermocouple output was stable throughout the test and correlated to within 50°R of a second thermocouple measuring mean exit gas temperature (tie rod flow plus fuel channel flow). Figure 2 shows the assembly, including the protection cup, after the final cycle. This cup had been tested previously for over 20 minutes at 4300°R. Figure 3 shows the thermocouple after the final cycle. The only observable damage was a slight blistering of the sheath near the thermocouple support assembly. This did not have any effect on the thermocouple. These were the final tests of the NRX-A6 proof tests. No further activity is planned.

TFL-1. d Orifice Calibration and Test

(U) Flow acceptance limits and loss coefficients for each of the 16 orifice sizes to be used for the NRX-A6 reactor have been established. The flow limits

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FIGURE 1

PEDESTAL, CUP, AND WASHERS AFTER FINAL TEST CYCLE
(TFL-1.a.0017c)

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FIGURE 2

THERMOCOUPLE ASSEMBLY INCLUDING PROTECTION CUP
AFTER HIGH TEMPERATURE TEST (TFL-1.a.0017c)

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FIGURE 3
THERMOCOUPLE-TIE ROD ASSEMBLY AFTER HIGH TEMPERATURE TESTS
(TFL-1.a. 0017c)

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and loss coefficient for the 12 orifice sizes used for the NRX-A3 reactor were used for the NRX-A6 reactor since the only test requirement which changed was the gas inlet pressure. The gas inlet pressure was 675 psia for the A3 and 705 psia for the A6 reactor. A test on a 24 mil orifice was conducted at each of these pressures. The loss coefficient as a function of Reynolds Number was the same for both tests.

The diameter of the flow channel of the three sizes of orifices tested during this period were 19, 20, and 21 mils. The basic design of the orifices had to be revised to permit fabrication. A counterbore of 52 mils in diameter and 185 mils deep was made from the outlet end of the orifice. As predicted from an analytical determination of the loss coefficient for the new orifice design, the loss coefficient for each flow channel diameter was lower than the values extrapolated from the NRX-A3 loss coefficient data.

In the process of establishing the loss coefficients of the 19, 20, and 21 mil orifices, 82 orifices were measured. Two diameters perpendicular to each other were measured at the inlet end and outlet end of each of the orifices. The average flow channel diameter was determined for each of the sizes to be tested. This process insured that the master orifice selected would not result in a large rejection rate when the production orifices were flow tested by Quality Control. At least four candidate orifices of the average diameter of the three sizes were selected to be flow tested. A total of 30 tests were performed on the 13 candidate master orifices for the three sizes of interest. At least two tests were performed on each orifice. Test conditions were as follows: inlet temperature - $\sim 140^{\circ}\text{R}$; inlet pressure - ~ 705 psia; flow media - hydrogen.

Three samples of graphite orifices furnished by Union Carbide were flow tested in the same manner as the NRX-A6 orifices with the exception that a simulated cluster plate was omitted from the test rig. The samples were pyrolytic

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graphite blocks 1" x 3/4" x 1/8" thick with a hole in the center drilled with a Number 80 (0.0135) drill. The hole in the graphite obtained in this manner was tapered and oval. All three samples tested exhibited essentially the same loss coefficient as a function of Reynold's Number. Because of the geometric differences, no direct comparison of coefficients are possible.

TFL-2. a Filler Strip Corrosion Tests

The reduction, compilation, and analysis of data from the last NRX-A6 test (TFL-2. a. 0002) continued at a relatively low level of effort. There were no substantial changes to the preliminary data presented at the last meeting. The results are being employed for the thermal design of the next test (TFL-2. a. 0003). The hardware for this model has been received and inspected, and the mock-up assembly and dimensional inspection was completed. The anti-friction liners have been installed on the filler strips and dimensionally inspected. Assembly of the model is proceeding on schedule for a September 15 test date. Thermal analysis is continuing in order to establish the required heater performance. If possible, the same heater design as in the last test will be used. If required, the heater will be modified by selective removal of coating and further sculpturing of the geometry.

The installation of the new periphery test facility will continue in order to bring the furnace on-stream by January, 1968. The furnace and stand are available and have been partially prepared. The test cell internal structures have been installed. Design and procurement of the flow loops, control consoles, data acquisition equipment, power supply, and auxiliary systems will begin after completion of the NRX-A6 tests. The NR-1 periphery model design, which has been initiated, will also continue during the remainder of this year.

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EML-D.1 Lateral Support Spring Relaxation Test

(UNC) Temperature-load tests on three NRX-A6 reactor grade lateral support springs (P/N 979D482) were conducted to determine set versus temperature. These springs are used in the reactor in the first three rows of the lateral support system. The results of similar tests on the springs used in the remaining rows have been previously reported.

(UNC) Tests were conducted on the springs by compressing them to the minimum operating length that the spring could experience in the reactor, which is 3.300 inches. The first spring was held at room temperature for 120 hours, the second spring was held at 1250°R for one hour, and the third spring was held at 1400°R for one hour.

(UNC) The free length and load to compress each spring to 3.300 inch length was measured before and after each test.

(UNC) No measurable set or significant load change occurred after the 530°R and 1250°R temperature tests, but a set of 0.026 inches occurred after the 1400°R test.

(UNC) These test results indicated a satisfactory spring design since the maximum spring temperature anticipated in the NRX-A6 reactor is 1066°R and only a small portion of the spring sees that temperature.

EML-E.2 A-6 Particle Catcher Tests

(UNC) Tests of a representative section of the A 6 particle catcher were performed at ambient temperature to determine wear and damage of contact surfaces caused by friction forces that result from core movements.

(UNC) A 35° simulated dome end section of the core periphery and reflector (Figures 4 and 5) approximately 6 inches long with A-6 prototype particle

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FIGURE 4
SIMULATED CORE PARTICLE CATCHER
SEAL SEGMENT ASSEMBLY
EML-E.2

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FIGURE 5
SIMULATED CORE PARTICLE CATCHER
PLATE ASSEMBLY
EML-E.2

(UNC) catcher assembly was tested by mechanically displacing the core section relative to the reflector section as follows:

1. Radial Displacement

(UNC) The radial movement from the assembled position was 0.116 inches toward the reflector and 0.106 inches away from the reflector. Ten cycles were made.

2. Axial and Tangential Displacement

(UNC) The axial movement from the assembled position (Station Zero) was 0.226 inches toward the dome end and 0.312 inches toward the nozzle end. The tangential movement from the assembled position (Azimuth Zero) was 0.133 inches in either direction. Ten cycles of each displacement were made.

3. Axial and Tangential Displacements Combined with Core Radial and Filler Strip Displacements

(UNC) Axial displacements were performed while extreme offset positions of core radial displacement and filler strip positions were maintained. The radial displacements of the core section were 0.116 inches either side of the nominal assembly position. The filler strip positions were as follows; filler strips 937J521 H05, H06 and H07 0.240 inches forward of Station 0; filler strip 937J521 H08 0.120 inches forward of Station 0; filler strips 937J521 H09, H10 and H11 were free to move axially within limits between the keyway in the filler strips and key in the partial elements. The core section was displaced tangentially while the filler strips were held in this offset position.

The axial displacement from the initial test position was 0.312 inches aft. The tangential displacement from the initial test position was 0.133 inches in either direction.

4. Axial Displacement with Unrestrained Filler Strips

(UNC)

During this test, the filler strips were free to move axially within limits between the keyways in the filler strips and keys in the simulated partial elements.

(UNC)

The axial movement from the assembled position (Station Zero) was 0.226 inches toward the dome end and 0.142 toward the nozzle end. Ten cycles of each displacement were made.

(UNC)

The above test conditions simulated the maximum possible displacements that could occur during transportation or operation of the reactor.

(UNC)

Post-test visual inspection revealed that the particle catcher plates rotated slightly from the axial aligned position. A layout study was made of the particle catcher and mating components considering the rotation that did occur. This study showed that under adverse tolerance conditions a potential interference between the particle catcher cover and a filler strip spacer plug could occur. Therefore, as a result of these tests, the hole in the particle catcher cover which accommodates the spacer plug was increased in diameter to preclude interference.

(UNC)

After inspection and modification of the parts, reassembly of the unit was made and the test was repeated. Post-test visual inspection after the repeat test revealed insignificant rotation of the particle catcher plates.

(UNC)

There was also no evidence of any significant wear between rubbing surfaces of the particle catcher parts. See Figure 6.

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FIGURE 6
PARTICLE CATCHER AFTER TEST
EML-E.2

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EML-E.4 Radial Loading of Filler Strip Orifice Plugs

(UNC)

Due to the thermal expansion and contraction cluster plates transmit transverse (radial) loads to the NRX-A6 filler strips. The load path is the friction interface between cluster plate and orifice plug. A schematic of the design is shown in Figure 7. Two series of tests were conducted to evaluate the magnitude and effects of these loads.

(CRD)

During the first series of tests, loads ranging from 15.8 to 76.6 lbs were required to fail the filler strips. These forces were applied directly to the ends of the orifice plugs.

(CRD)

A second series of tests were conducted to determine the coefficient of friction between the orifice and cluster plate interface. The results indicate this value to be approximately 0.21 which means that axial load in excess of 75 lbs would be required for a failure condition to exist. The maximum normal spring load for NRX-A6 operating conditions is 65 lbs. Therefore, a condition must occur in which more than one spring load is reacted by a single orifice plug to develop an axial load in excess of 75 lbs. Further analysis is planned to determine if this is possible.

Static Axial Load Capability of NRX-A6 Interlocking Filler Tiles and Filler Strips

(CRD)

Interlocking filler tiles and filler strips serve as a redundant axial support concept at the NRX A6 core periphery. A schematic of the design is shown in Figure 8. Filler tiles inserted into filler strip grooves are seen bridging two adjacent filler strips. This interlocking design is loaded when excessive relative axial displacements between two adjacent filler strips occur. Static load tests have been completed to evaluate the ultimate load capability of this design and the mode of failure.

FIGURE 7
RADIAL LOADING OF FILLER STRIP ORIFICE PLUGS
EML-E.4

FIGURE 8
SCHEMATIC OF NRX-A6 INTERLOCKING
FILLER TILES AND FILLER STRIPS
EML-E.4

(UNC) Nine tests were performed simulating the loading condition between pairs of adjacent filler strips in core positions 10 and 11, 18 and 19, 27 and 1. A schematic of the test arrangement is presented in Figure 9. Simulated filler strip grooves 1-3/4" long were machined into the test pieces and islands on either side of the groove positioned a 70 mil thick slab of tile backed by layers of 5.5 mil grafoil. The lab test setup is shown in Figures 10 and 11.

(CRD) Test results summarized in Table III show that damage occurred at the loaded filler strip ledges as cracks and chips in all nine tests. Failure loads ranged from 144 lbs to 205 lbs with an average of 167 lbs. Since all filler strip failures occurred locally in the loaded edges, the test results are independent of differences in filler strip cross-sectional geometry. Examples of this damage are shown in Figure 12. Seven of the tile pieces had chipping at the corners as shown in Figure 13, but since this damage was slight compared to tile bearing failures it is considered secondary. Figure 14 shows the one case (Test 9 of Table III) in which cracks also appeared in the filler tile.

(CRD) The maximum calculated NRX-A6 pressure drop load at this loading interface is 79 lbs. The strength of interlocking filler tiles and filler strips is therefore adequate for this design condition.

Ultimate Load Capability of NRX-A6 Filler Tile

(UNC) The testing described in the previous sections established the mode of failure and the ultimate axial load capability of interlocking filler tiles and filler strips. In eight of nine tests it was evident that the initial failure occurred in the filler strips. Additional tests were performed to determine the ultimate load capability and mode of failure of the filler tile.

FIGURE 9
SCHEMATIC OF TEST LOADING CONDITION
EML-E.4

FIGURE 10
NRX A6 INTERLOCKING FILLER TILE -
FILLER STRIP TEST RIG
EML-E.4

FIGURE 11
NRX-A6 INTERLOCKING FILLER TILE— FILLER STRIP TEST SETUP
EML-E.4

TABLE III
 ULTIMATE AXIAL LOAD CAPABILITY OF INTERLOCKING
 A6 FILLER TILES AND FILLER STRIPS
 EML-E.4

Filler Strip Pair	Test	Failure Load (lbs)	Failure Description Filler Strips (at loaded edges)	Filler Tile
18 & 19	1	147; 160	No. 18: Fine crack and large chip at 147 lbs. Crack enlarged when re-loaded to 160 lbs. No. 19: No apparent damage.	Chipping at one corner.
	2	175	No. 18: Large cracks and chips. No. 19: Large cracks and chips.	Chipping at one corner.
	3	167	No. 18: Large cracks and slight chipping. No. 19: Large cracks and slight chipping.	Slight chipping.
27 & 1	4	148	No. 27: Large cracks and chips. No. 1: No apparent damage	No apparent damage.
	5	144	No. 27: Noticeable crack and chipping. No. 1: Crack initiation and small chip.	Chipping at one corner.
	6	156	No. 27: Noticeable crack and slight chipping. No. 1: No apparent damage.	No apparent damage.
10 & 11	7	171	No. 10: Crack along the ledge bearing surface. No. 11: No apparent damage.	Chipping at one corner.
	8	205	No. 10: Large crack and large chip. No. 11: Noticeable crack.	Slight chipping at one corner.
	9	188	No. 10: Fine crack. No. 11: Ledge cracked along load bearing surface. Some chipping.	Cracks along two edges of the tile.
Average Failure Load 167 ⁺³⁷ / ₋₂₃ lbs.

FIGURE 12
TYPICAL FILLER STRIP FAILURES (TEST 7)
EML-E.4

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FIGURE 13
TYPICAL FILLER TILE DAMAGE
EML E.4

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FIGURE 14
FILLER TILE DAMAGE IN TEST 9
EML-E.4

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(CRD)

Three tile pieces were tested to failure in simulated filler strips made of aluminum (Figure 15). The initial failures occurred as bearing failures along the loaded edges of the tile at an average load of 167 lbs (see Table IV). Since this is the same average load at which the filler strip failures occurred, it implies that filler tile bearing failure is impending when the filler strip fails.

(CRD)

The tile specimens were reloaded to determine the performance of filler tile beyond initial bearing failure. Continuous loading was possible up to loads ranging from 55% to 66% of the initial failure loads (see Table IV). This data indicates a reduction of load area from 1/3 to 1/2 as the material compacts at the ultimate bearing stress. Further loading was possible only in erratic manner. Under this loading the tile sheared and became delaminated as might be expected. The loads supported during this failure mode appear in Table IV. The final appearance of the test pieces is shown in Figure 16 .

TABLE IV: Ultimate Axial Load Capability of the Filler Tile

Test	Initial Failure Load (lbs)	Initial Tile Damage	Initial Reload (lbs)	Reload Range	Observations
1	184	Bearing failure	100	100-176	Fluctuating load in the reload range due to shearing & delamination of the filler tile in all three tests.
2	164	at loading	85	85-120	
3	152	in all three tests	100	100-135	
Average Failures	167 ⁺¹⁷ -15		95 ⁺⁵ -10		

(CRD)

FIGURE 15
LABORATORY RIG TO DETERMINE ULTIMATE STRENGTH
OF NRX-A6 FILLER TILE
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FIGURE 16
FINAL APPEARANCE OF TESTED
FILLER TILE SPECIMENS AND 5.5 MIL GRAFOIL
EML-E.4

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Central Element Tension Tests

(CRD)

Center elements for the NRX A6 reactor which are to contain thermocouples have three axial holes at three corners 120° apart. The A-6 center bore and the O.D. are coated, but the three thermocouple holes are not. Inspections have indicated corner surface cracks over the three TC holes. The cracks are radial from the surfaces towards the hole and are random along the length of the element.

(CRD)

Tests were conducted to determine if the corner cracks found in the instrumented NRX A6 central elements caused a decrease in their tensile capability during friction lock-up. The test rig reported in WANL-TME 1555 (January, 1967, Fuel Element Tension Test Results at Room Temperature; by Zibritosky) was used to conduct these tests. Test specimens from two NRX A6 elements with T.C. holes were compared to test specimens from an NRX-A6 element without T.C. holes. The data is summarized in Table V .

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TABLE V

Specimen Type	Test Number	Element Serial Number	Station		Fracture Strain 10^{-6} in/in.
			Specimen	Fracture	
A-6 Central	1	61933	8.5-16	12.2	2275
Coated Element	2	61933	24.2-33.2	28.2	1900*
With 3 T.C. Holes	3	61933	34.2-43-8	39.8	2120
(CRD) A-6 Central	4	61943	0-10	5.4	2120
Coated Element	5	61943	10-20	14.9	2050
With 3 T.C. Holes	6	61943	22-32	27.6	1955
	7	61943	32-42	38.6	1920
A-6 Central	8	76518	10-20	14.3	2130
Coated Element	9	76518	20-30	23.7	2350
No. T.C. Holes	10	76518	40-50	44.3	1980
Uncoated Central	11	99150	10-20	14.7	2485
Uncoated 13-Hole Central	12	94514	10-20	16	2520

* Failure occurred during a second test cycle of the specimen.

NOTE:

- (UNC) 1. Fracture strain is the average value of 6 strain gages on 3 of the 6 periphery elements. The values are from the 6 gages nearest the axial position of the fracture location. Complete friction lock-up is assumed hence values in the periphery elements and the specimens are equal.
- (UNC) 2. Values of fracture strain are comparable to those values for fueled elements reported in WANL-TME-1555 (this report also describes the test rig).
- (CRD) 3. It appeared that fracture locations often were at known crack locations.

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EML-E.2 Adhesive Residue Evaluation

(UNC)

It was originally intended to use silicone grease for holding individual wrapper strips to the filler strips and to each other during wrapper assembly. This compound was satisfactory for assembly use since it was tacky enough in very thin films to hold the layers in place, and yet non-hardening. The latter feature allows shifting of the layers and thus facilitates a wallpapering type alignment technique on the sheet to sheet joints in a given layer.

(CRD)

After disassembly of a recent HTT-1 test, it was observed that a deterioration of the wrapper seemed to coincide with large white deposits resulting from the silicone grease. Also, observations made during the friction tests which were part of the qualification of materials for attaching the A6 slip plane strips indicated that silicone grease produced a high friction interface. Paraffin, which was ultimately qualified for the slip plane attachment was unacceptable for the wrapper assembly application because it hardened rapidly and caused problems in the alignment of the sheets.

(CRD)

Three additional materials were then considered for this application and an evaluation made of their residue characteristics. Table VI gives the results of this evaluation. Tests were conducted by placing a thin coating of adhesive on two pieces of foil which were then joined together with the adhesive sides in contact. Separate runs were then made at temperatures of 2000°R, 3000°R, and 4500°R in a hydrogen atmosphere which was maintained in the furnace with an 8 SCFM through flow. A uniformly distributed mechanical load of 30 psi was applied to simulate the bundling force. All of the test components as well as the Petrolatum test samples are shown in Figure 17 .

TABLE VI

(UNC)	<u>Adhesive</u>	<u>Sample Treatment</u>	<u>Wt. of Residue (mg)</u>
	Apiezon T	2000°R	0.0
		3000°R	0.0
		3800°R	0.0
		4500°R	0.0
	Apiezon N	2000°R	0.0
		3000°R	0.0
		3800°R	0.0
		4500°R	0.0
	Petralatum	2000°R	0.0
		3000°R	0.0
		3800°R	0.0
		4500°R	0.0
	Silicone Grease	2000°R	1.3
		3000°R	1.6
		3800°R	1.7
		4500°R	0.3
	Paraffin	2000°R	0.0
		3000°R	0.0
		3800°R	0.0
		4500°R	0.0

- (1) X-ray diffraction determinations on the samples bonded with Silicone Grease identify the residue as silicon metal.
- (2) Silicone Grease and Paraffin included for reference.

FIGURE 17
EML-E.2

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(UNC) After testing all foils separated easily except those from the 3000^{OR} silicone grease test. Also, residues were only observed when silicone grease was used. All samples were then analyzed for residues by the WANL Physical Sciences Laboratory. The residues from the silicone grease (the only ones detected) were identified as a silicon material by an X-ray diffraction technique.

(UNC) These test results coupled with assembly tests showed that either Apiezon T or Petrolatum would be acceptable. Friction characteristics of both were found to be similar and Petrolatum was chosen because Supplier furnished data showed that Apiezon T contained stearates, a potential source of abrasive matter.

EML-G.1 Exit Gas T/C Vibration Test

(UNC) An NRX-A6 recrystallized exit gas thermocouple was vibration tested to determine whether its function was adversely affected by high temperature operation. A previously used thermocouple and the associated hardware were assembled at the end of a shortened tie rod which was inserted through a steel fixture block and the tie rod nut tightened. This assembly, shown in Figure 18, was mounted to a horizontal thruster and outputs from the control accelerometer and the semiconductor strain gage were monitored on an oscilloscope. The complete test setup is shown in Figure 19.

(CRD) Vibratory loads were applied in the direction parallel to the center-line of the tie rod and perpendicular to the axis of the thermocouple. Sweep tests were performed in the frequency range of 15 to 5000 cps at input acceleration levels of 5 and 10 g's. Resonances noted during these levels were in the frequency range of 2516 and 2627 cps.

FIGURE 18
TEST SPECIMEN ASSEMBLY
EML-G.1

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FIGURE 19
TEST SETUP
EML-G.1

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(UNC) Table VII is a summary of the resonances as noted by the strain gage outputs. Also shown are the frequencies at which the strain gages are approximately at the 70% of the maximum outputs. These values indicate a low damped system with a relatively sharp resonance buildup. Because of this the exact 70% point could not be selected exactly.

(UNC) Figure 20 is a photograph of the strain gage output signal at the resonant frequency as monitored on the oscilloscope.

(UNC) The resistance to ground and continuity of the circuit checked before and after testing indicated that no damage had occurred to the thermocouple.

EML-B.3 Transportation Test of NRX A6 Poison Rods

(UNC) A low frequency shipping test was performed to ascertain the effect of the poison rods on the molybdenum and niobium coatings on NRX-A6 fuel elements.

(UNC) The first series of tests were performed to determine the effect that inserting and extracting of poison rods have on the coating in the flow holes of a fueled element.

(UNC) Two fueled elements were weighed to the nearest hundredth of a gram. Figure 21 shows the measuring system. Six poison rods, arbitrarily chosen from a group of ten, were inserted in a consecutive fashion, ten times in each of six predetermined fuel element flow hole locations. Figures 22 and 23 illustrates the selected hole pattern. The poison rods were inserted from the aft end with the element in a horizontal position on a table. A clean sheet of blotter-type paper was used to collect all materials that were removed from the element during poison rod removal. Upon completion of these tests, the fueled elements were reweighed. Table VIII gives the results of these tests.

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TABLE VII

Acceleration Level	Frequency At $\approx .70\epsilon_R$	$\approx .7\epsilon_R$ (μin) Below	Resonance	ϵ_R	Frequency At $\approx .7\epsilon_R$	$\approx .7\epsilon_R$ Above	Time At Level
1	-	-	2627	61	-	-	30 sec
2	-	-	2618	86	-	-	30 sec
3	-	-	2613	101	-	-	30 sec
4	-	-	2599	123	-	-	30 sec
5	2518	98	2598	123	2647	91	30 sec
10	2365	113	2585	152	2641	120	60 min
20	2511	125	2586	184	2657	123	10 min
30	-	-	2516	196	-	-	30 sec

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24.6 μ in

FIGURE 20
Typical Oscilloscope Trace
2598 cps 5 g's
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FIGURE 21
INSTRUMENT TO MEASURE WEIGHT OF FUELED ELEMENTS
EML-B.3

FIGURE 22
HOLE PATTERN FOR INSERTION OF POISON RODS
EML-B.3

FIGURE 23
FUELED ELEMENT SHOWING SELECTED HOLE PATTERN
EML-B.3

TABLE VIII

	Element No.	Weight Before Insertion	Weight After Insertion	Loss
		gms.	gms.	gms.
(CRD)	AC-16-39493	665.60	665.59	.01
	AC-16-39494	666.57	666.52	.05

(UNC) Another series of tests were performed to determine the effect that poison rods have on the fueled elements when subjected to low frequency shipping vibrations.

(UNC) Six poison rods were inserted in the same coolant channels as described above. The apparatus shown in Figure 24 was used to apply the following inputs:

Frequency	1.1 cps	2 cps	4 cps
Acceleration	0.5 g	0.4 g	0.35 g
Duration	12 hr	12 hr	3 hr

(UNC) The tests were completed for each frequency in the order before starting the next test, i.e., 12 hours at 1.1 cps, 12 hours at 2 cps, and 3 hours at 4 cps. Each fuel element was positioned separately in the test apparatus fixture shown in Figure 24 so that only rigid body motion was induced, the vibration being produced by an eccentric arm on a variable speed motor. The following table lists the weight of each element before and after testing.

TABLE IX

	Element No.	Initial Wt., gms.	After Vibration	Loss
			(27 hours)	gms.
(CRD)	AC-16-39493	665.59	665.58	.01
	AC-16-39494	666.56	666.55	.01

(UNC) The significance of the weight loss for these tests is being evaluated. The quantity of material collected was too minute for analyzing as to its composition.

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FIGURE 24
FRONT VIEW OF LOW FREQUENCY VIBRATION FIXTURE
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TESTS FOR NR-1

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EML-B.3 Poison Wire Removal Tests

(UNC) The purpose of this test program is to obtain NR-1 design information concerning the manner in which the force needed to extract the position wires from the cluster assembly varies with:

- a) the cluster assembly temperature,
- b) the exit angle of the poison wires from the cluster assembly,
- c) the poison wire exit velocity.

(UNC) Although ten poison wires were selected for the testing, the results can be extrapolated for a full assembly.

(UNC) The experimental test system shown in Figures 25 and 26 consists of the supporting structure and the necessary instrumentation. The functions of the superstructure are to allow variations in exit angle for the poison wires and to house the displacement of the ten poison wire bundle. The pulley, upon which the lead wire from the end of the poison wires is wrapped, is seen in Figure 26. At the top of this figure the displacement gage is seen and in the foreground the variable drive control for the constant speed motor (rear of motor is shown to the left of the pulley in background). Figure 27 shows a schematic sketch of the test setup. Views of the top of the cluster assembly for a poison wire prior to and after extracting at an angle of 45° are shown in Figures 28 and 29. The output signal from the transducers was used to drive a X-Y Recorder where the force was plotted on the ordinate and the displacement signal on the abscissa. Prior to the dynamic test, static or break-away loads were determined by a dead weight loading. By measuring the weight of metal pellets added to a container connected to the lead wire, the force necessary to cause movement

FIGURE 25
SUPPORTING STRUCTURE FOR POISON WIRE EXTRACTION TEST
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FIGURE 26
VIEW OF POISON WIRE EXTRACTION PULLEY,
DISPLACEMENT GAGE, VARIABLE DRIVE CONTROL
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FIGURE 27
 SCHEMATIC OF TEST SETUP
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FIGURE 28
VIEW OF 45° EXTRACTION ANGLE OF POISON WIRES -
INITIAL CONDITIONS
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FIGURE 29
VIEW OF 45° EXTRACTION ANGLE OF POISON WIRES -
FINAL CONDITIONS
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was noted. The results of the static and dynamic tests are given in Figure 30

(UNC) The static break-away force increases for an increasing poison wire exit angle and is proportional to the length of wire remaining in the cluster assembly.

(UNC) The plots of the dynamic tests indicate that as the exit angle and velocity increase so does the peak force. The peak load approximately occurs at an exit angle of 45° and a velocity of 7 in/sec.

(UNC) The second phase of this test program will entail tests at temperatures approaching liquid nitrogen. To eliminate frost from forming at the support block, a housing was constructed to enclose the exit end of the cluster assembly and a flow of argon was used to purge the system of moisture.

(UNC) Although the ten wires available for testing were indicating signs of cracking, no damage to the support block was attributed to the extractions performed. During checkout of the system at cryogenic conditions damage did occur at the axial hold down clamps. This damage due to differential expansions of material will be eliminated in future tests since axial hold down springs have been added.

EML-C.1 Pedestal Thermal Shock

(CRD) Continued thermal shock testing of a graphite pedestal achieved temperature rises greater than $300^\circ\text{R}/\text{sec}$ to 3900°R (Figure 31). These higher rates and maximum temperatures were accomplished in the present fixture consisting of a single element heat exchanger at 5000°R . All test data was successfully recorded on the VIDAR System with data points during heatup recorded at 1 per sec. Five cycles were conducted with helium at flow rates of 60 to 100 SCFM through the heat exchanger. Post test observations showed no cracking in the pedestal. However, the

FIGURE 30
PLOT OF POISON WIRE EXIT ANGLE
VS
EXTRACTION FORCE
(AMBIENT CONDITION)
EML-B.3

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FIGURE 31
TEMPERATURE PROFILE OF GRAPHITE
PEDESTAL THERMALLY SHOCKED IN SINGLE ELEMENT FIXTURE
EML-C.1

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thermocouple melted below the transition since temperatures greater than 3500°R were recorded in this area and modifications are being made to protect thermocouples from excessive temperature at this point. A redesign of the specimen holder and the incorporation of quick heatup features are also underway.

EML-E.1 Overlapped Wrapper Test

(UNC) A prototype NR-1 wrapper was run in the EML E.1 Rig to investigate the feasibility of a wrapper with lapped joints under conditions of reactor temperature, pressure difference and expansion.

(UNC) During assembly of the wrapper, axial gaps occur between the strips of foil. These are of concern since they represent possible axial leak paths which could become sources of corrosion. In addition to the usual objective of checking wrapper integrity during expansion under reactor conditions, a specific objective was to see if the interstitial gaps caused by the lapped joints would be eliminated at temperature to make a tight axial joint and allow the filler strips to assume smooth periphery. This investigation was prompted by (1) the knowledge that the foil is quite ductile at high temperature, (2) the design of a lapped joint wrapper periphery could otherwise be complex.

(CRD) The results illustrated by Figures 32 and 33 show the core segment after bundling cold to the seal spring pressure and after hot operation with a 20 psi pressure difference across the foil and average foil temperatures of 2500°R. The attempts at hot forming as seen in Figure 33 were not successful and it appears that the elimination of axial gaps in the lap joint design will require considerably more design and development effort than the more successful butt joint design reported last month.

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FIGURE 32
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FIGURE 33
EML-E.1

(CRD)

The solutions to the problem which immediately present themselves are as follows: 1) A foil preforming process which uses higher temperatures and pressures. 2) Tapering of the foil from 5-1/2 mils down to zero. 3) Locally modified filler strips to provide the required clearance at the overlap.

(UNC)

No adverse affect on wrapper integrity was observed as a result of this test. However, test conditions were somewhat less severe than those expected under NR Reactor operation, because excess heat leaks in the rig prevented the achievement of full reactor temperature and the use of NRX hardware limited the expansion to about 1/2 of that expected in the NR reactor. A significant achievement during this test was the hook-up of the E.1 Rig to the EML Digital Data System and the processing of the data into the form of the sample curves shown as Figures 34 and 35. These represent the temperatures of the foil closest to the fuel and the 10th layer of foil at filler strip 22 as shown in Figure 36. Figure 37 shows the hottest layer after the test with one side of the layer displaced to show that the overlap is the same width as a fuel element flat.

EML-A.4

Band Fatigue Tests

During initial checkout of the band test fixture, two problems became apparent:

(UNC)

1. The clamp at the cable end of the band load system did not develop sufficient friction force to prevent failure of the band at the reduced section where bolt holes penetrated the band to facilitate attachment.

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FIGURE 34
TEMPERATURE PROFILE HOT SIDE OF WRAPPER
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FIGURE 35
TEMPERATURE PROFILE COLD SIDE OF WRAPPER
EML-A.4

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FIGURE 36
 EML E.1

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ENGINEERING MECHANICS LABORATORY

DATE 7-12-67 EML NO E-1

TEST NO BUILD 1 TEST 1 RUN NO A-7 PERIPHERY

SPECIMEN 10 LAYERS .005 FOIL WITH LAPPED JOINTS

TEST INVESTIGATE FEASIBILITY OF LAPPED WRAPPER JOINTS, OBTAIN THERMAL DATA FOR WRAPPER INSIDE FILLER STRIPS

0 2 4

FIGURE 37
EML-E.1

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(UNC) 2. The cables used untwisted under tensile load
thereby imparting a twist to the band during cycling
operation.

(UNC) Both conditions are unacceptable and redesign of the holder has been
accomplished and new cable has been installed. Testing will be initiated
during the next period.

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GENERAL DEVELOPMENT TESTS

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

(C-RD) There were 39 single element tests conducted during the period. Ten of the elements tested were part of Phase I-3B of the Fuel Assessment Program. These were Phoebus 1B fuel elements tested at LASL conditions with a $\Delta P_{20} = 30$ psi. Nineteen were high void elements from Phase II-Fa, two elements from Phase I-B, two elements from Phase IIA-2a and nine from Phase I-D. There were four tests conducted for chuck development, two of a multi-fingered chuck and two to determine if movement of the element downstream in the hot end chuck would result in improved hot end performance. There was one element tested to evaluate the long air impedance probe and a linear displacement potentiometer. Three tests were conducted as part of the NRX-A6 O.D. coated element evaluation test program and two elements were tested as part of Phase I-4B at NRX-A6 conditions. An analysis of the water injection system, which was installed in order to reduce the gas temperature ahead of the heat exchanger, was performed. The results showed, that because of the increase in the heat transfer coefficient, the tube temperature in the heat exchanger will actually increase when water is added. Water injection tests have been postponed as a result of this analysis. Tests of high void elements from Phases IIA-2a and I-D, chuck development tests, and methane corrosion inhibition tests are planned for the next period.

TFL-5. b Interstitial Corrosion Tests

(U) Three tests studying the corrosion characteristics of different "grafoil" geometries were conducted during the review period.

(C-RD) The first configuration was a nine layer NRX-A6 wrapper simulation using 0.0055 inch thick nonthermalized reactor grade material. The flow slot measured 0.006 inches thick by 0.280 inches deep by 2 inches long with the 0.006 inch thickness exposed to the foil in the standard filler strip gap orientation. The test conditions and results are as follows:

Test Number	TFL-5. b. 045
Test Time (min.)	30
Inlet Pressure (psig)	350
Inlet Gas Temperature (°R)	534
Average Material Temperature (°R)	3503
Flow Rate (lb/sec-H ₂)	4.27×10^{-5}
Graphite Weight Before Test (gms)	81.673
Graphite Weight Loss (gms)	0.266
"Grafoil" Stack Weight Before Test (gms)	1.681
"Grafoil" Stack Weight Loss (gms)	0.123

Coupon Weight Losses for Multi-Layer Test
Test Number TFL-5. b. 045

Pre Test Weight Loss	Coupon No.	Post Weight (gms)	Weight Loss (gms)
0.195	1	0.166	0.029
0.193	2	0.173	0.020
0.200	3	0.182	0.018
0.207	4	0.191	0.016
0.167	5	0.156	0.011
0.182	6	0.171	0.011
0.185	7	0.180	0.005
0.160	8	0.153	0.007
0.192	9	0.186	0.006
1.681		1.558	0.123

(U) Figures 38 and 39 show the general configuration and the nine "grafoil" coupons comprising the stack. Figure 40 shows the fit of the nine layers in the window of the NbC coated specimen. During the test, it was noticed that the pressure drop across the specimen was low when compared to the 0.010 inch coupon tests. This condition could have been created by one or both of two factors, one being the increase in coupon window depth to 0.060 inch, and the other being the separation of the specimen halves by differential expansion of the coupon stack.

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FIGURE 38

GENERAL CONFIGURATION OF MULTI-LAYER FIXTURE

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FIGURE 39
INDIVIDUAL COUPONS

FIGURE 40
COUPON FIT IN FIXTURE WINDOW

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(U)

The weight loss data indicates that the majority of damage took place opposite the flow slot which was expected. Width and length measurement show that corrosion was experienced on all edges of the stack for the full thickness. The total growth of the coupon stack was 0.0004 inches more than calculated which made the interference between specimen and stack approach 0.001 inches rather than the calculated 0.0005 inches. This condition could have contributed to the low pressure drop. The weight loss of the graphite specimen is high as expected because the half containing the flow slot had been used in a prior test.

(C-RD)

The second configuration contained a 0.060 inch thick hot bonded laminate coupon opposite a 0.840 inch wide, 0.006 inch thick flow slot. This material was used to prevent bowing that was experienced when 0.010 coupons were tested in a similar configuration to study the effects of the area change on "grafoil" corrosion. Test conditions and results are as follows:

Test Number	TFL-5. b. 046
Test Time (min.)	15
Inlet Pressure (psig)	350
Inlet Gas Temperature (°R)	536
Average Material Temperature (°R)	3487
Flow Rate (lb/sec-H ₂)	8.52×10^{-5}
Pre Test Graphite Weight (gms)	81.820
Graphite Weight Loss (gms)	0.105
Pre Test Laminate Coupon Weight (gms)	2.723
Laminate Coupon Weight Loss (gms)	0.259

(U)

Figures 41 and 42 show the general specimen configuration and the fit between window and coupon. Upon disassembly, the corrosion pattern on the coupon indicated that a slight bowing condition existed which diverted the hydrogen to the edges of the flow slot causing a small hump along the coupon's center line. Corrosion along the edges of the coupon was present even though the fit in the window was the closest obtained to date. Figure 43 shows that delamination of the material took place on the edges.

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FIGURE 41

GENERAL CONFIGURATION OF 0.060 INCH THICK LAMINATE FIXTURE

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FIGURE 43
EDGE CORROSION ON THE LAMINATE COUPON

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(C-RD)

The third configuration consisted of a standard size hexagon wrapped with 0.0055 inch thick reactor grade "grafoil". This item was contained in a cup with a matching internal hexagon. The assembled system simulated the element impedance sleeve designed to interrupt interelement flow. The test is designed to show sealing characteristics and corrosion resistance of the "grafoil" seal. Test conditions and results are as follows:

Test Number	TFL-5. b. 047
Test Time (min.)	30
Inlet Pressure (psig)	350
Inlet Gas Temperature (°R)	538
Average Material Temperature (°R)	3514
Flow Rate (lb/sec-H ₂)	3.28×10^{-6}
Pre Test Hexagon Weight (gms)	26.983
Hexagon Weight Loss (gms)	0.061
Pre Test Cup Weight (gms)	61.205
Cup Weight Loss (gms)	0.211

(U)

Figure 44 shows the general configuration of the specimen. The "grafoil" was held in place by sealing wax after the "grafoil" was bent to the hexagon shape. Figure 45 is a photograph of the assembled fixture lighted from the bottom. The figure shows what areas are open to flow and the general order of magnitude of the gaps.

(U)

During the test, only a small increase in pressure differential was noticed as the specimen temperature was increased. This indicated that the swelling of the "grafoil" during the thermalization process was not sufficient to seal the flow areas shown in Figure 45. It was also noted that the extremely small flow rate made control and measurement of pressure differentials difficult.

(C-RD)

When the hexagon was removed from the cup, separate weights were recorded and photographs of the items taken. Corrosion was evident on the "grafoil" around the entire inlet edge which gradually became more severe as the intersection of the sides of the hexagon are approached. This corrosion turned into

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FIGURE 44

GENERAL CONFIGURATION OF HEXAGON IMPEDANCE FIXTURE

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FIGURE 45

ILLUSTRATION OF FIXTURE FLOW AREAS BY BOTTOM ILLUMINATION

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local delamination of the "grafoil" toward the exit end of the fixture. The scarf joint proved to be subject to the most corrosion showing severe attack up to the first 90 degree bend in the joint. Figure 46 shows a photograph taken of the flat which contained the "grafoil" joint. The high weight loss on the cup was the result of the NbC coating removal when the assembly was being extracted from the specimen holder.

(U) Plans for the next four weeks call for the testing of two additional thick hot bonded laminate coupons opposite a 0.840 inch wide flow slot, test conditions undetermined. A composite material fixture will also be evaluated. It has been requested by Reactor Analysis that another hexagon configuration be tested at 3700°R; Reactor Analysis has also approved the extension of the temperature effect series basic configuration to other pressures.

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FIGURE 46

CORROSION ON SCARF JOINT OF IMPEDANCE SLEEVE

EML-A.2 Beryllium Properties

(UNC) A low cycle fatigue test at 140°R was completed on the final specimen fabricated from the NRX-A6 ring pressing. The .750 inch diameter specimen was cycled between the limits of ± 1700 microinches per inch strain before failure occurred at 2-3/4 cycles. The average plastic strain range during the test was about 1500 microinches per inch.

(UNC) A comparison with the other specimens machined from the same NRX-A6 ring pressing and cycled between the same strain limits indicated that a wide variation of cycles to failure existed between the specimens. The three specimens under the same test conditions failed at 43, 15 and 2-3/4 cycles.

(UNC) If we plot the plastic strain range vs cycles to failure on the curve of Coffin's modified criteria, (Figure 47) the test data indicates that a satisfactory correlation exists. However, a plot of strain amplitude vs. cycles to failure (Figure 48), shows a wide scatter band. Nevertheless if a straight line is drawn through the poorest 1700 microinch point (2-3/4 cycles) and parallel to the previously established lower probability curve, it indicates a failure time in excess of 1000 cycles for the 620 microinch tension strain calculated for the NRX-A6 reflector.

FIGURE 47
LOW CYCLE FATIGUE DATA ON BERYLLIUM BLOCK PRESSING NO. 3824
PLASTIC STRAIN RANGE VS CYCLES AT 140°F
EML-A.2

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FACILITIES
and
ACTION ITEMS

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Engineering Mechanics Laboratory Facilities

EML-E.2 Temperature Checkout of New Friction Furnace

(UNC) A temperature checkout test was performed on the high temperature friction test furnace to determine characteristics of the heating element. For the first test power was gradually increased until a power level of 1000 amperes and 28 volts was reached. The temperature reached at this power level was 4500°R. A second test was then performed at higher initial power settings. A power setting of 1340 amperes and 32 volts was attained within 30 seconds, and then reduced to 1270 amperes and 31.5 volts. A temperature of 4200°R was reached at this power level in 6 minutes. Based on these preliminary tests, it appears that the goal of 4500°R in three minutes can be achieved.

EML-H.1 XECF Resonant Survey

(UNC) The instrumentation trailer was tested over local roads and no equipment damage was incurred. The instrumentation shaker suspension fixture and drive rod with next be tested in a dummy test to check out the AGC-WANL integrated system. Calibration checks are now being conducted using a secondary accelerometer traceable to the National Bureau of Standards.

(UNC) The vibration instrumentation trailer will be shipped with the NRX-A6 controlled train shipment to the Test Site. Reports of "G" levels on these trips have been reviewed. The last trip encountered no "G" levels higher than .75 G's. This is about one-half of that which was encountered on the local road test of the trailer.

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(This Page is Unclassified)

WANL-TME-1670

FACILITIES

5000 Gallon Dewar

Approval for the installation of a 5000 gallon dewar at WANL has been obtained from the Safety Committee. The dewar now located at WANHES will be transferred to WANL upon receipt of the new vaporizer needed for use in conjunction with the dewar.

ACTION ITEMS

Air Impedance Gage

A second air impedance gage needed at WANHES has been procured from the Reactor Assembly Department. The gage will be calibrated and sent to WANHES as soon as possible. This will make available separate gages for use in the fit-up room and in the furnace.

Valves for Dual Furnace Operation at WANHES

The two 4-inch Associated Control Equipment butterfly valves which are required for dual furnace operation at WANHES have passed the manufacturer's leak test and should be delivered by August 31, 1967.

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