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Westinghouse Astronuclear Laboratory

NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW MEETING
HELD WITH SNPO AT WANL ON NOVEMBER 16, 1966

(Title Unclassified)

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Classification cancelled for change in
by authority of Doc
by H.E. R.C. J.S. SEP 10 1973

INFORMATION CATEGORY
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W. J. Rowan, Manager
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~~GROUP-1
Excluded from Automatic Downgrading
and Declassification~~

SPECIAL REVIEW FINAL DETERMINATION	Reviewers	Class.	Date
	TR	U	5-10-82
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NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW MEETING
HELD WITH SNPO AT WANL ON NOVEMBER 16, 1966

Attendees:

A. J. Bermingham	AGC	J. S. Olinger	WANL
E. A. DeZubay	WANL	W. J. Rowan	WANL
H. J. Fix	WANL	R. M. Saccocio	WANL
J. W. Fisch	WANL	J. J. Schreiber	WANL
W. J. Havener	WANL	R. J. Steffen	WANL
G. Kalvin	SNPO-C	F. G. Tauch	WANL
I. E. Kanter	WANL	D. C. Thompson	WANL
V. G. Kelly	WANL	E. A. Watjen	WANL
H. Murphy	SNPO-C	R. C. Wilke	SNPO-C

The Monthly Development Test Program Review Meeting was held at WANL on November 16, 1966.

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

The individual tests were then discussed in the order as shown in the Tables.

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TABLE I
FLUID FLOW LABORATORY TEST SCHEDULE

PERFORMED THIS PERIOD	PLANNED NEXT PERIOD
Tests for XE-1 FFL-1. a Cluster Test - Completed 37 Minutes on XE-1 Thermocouple	No Activity
Tests for NRX-A6 FFL-1. a Cluster Test - 65 Min. Completed on Skirtless Block With ATJ Cup 10 Min. on Skirtless Block With Tungsten Cup FFL-1. b Single Element Corrosion - Completed 188 Tests in Support of Fuel Assessment Program FFL-2. a Filler Strip - Completed Model Assembly FFL-6. a 360° Reactor Shield - Initiated Testing	60 Min. Tungsten Cup 60 Min. NbC Cup 60 Min. Exit Gas Thermocouple Continue Testing 60 Min. Test Continue Testing
General Development FFL-5. b Interstitial Corrosion - Mass Flow Effects FFL-5. c Permeability - Initiated Testing	Continue Testing Continue Testing
Facilities Guard Heater Power Supply - Initiated Installation	Complete Installation

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TABLE II
 ENGINEERING MECHANICS TESTING
 October, 1966

PERFORMED THIS PERIOD (Oct/Nov, '66)		PLANNED NEXT PERIOD (Nov/Dec, '66)	
Tests for XE-1			
EML-H.1 XECF Resonant Survey (EML-55)			
Tests for NRX-A6			
EML-A.2 Be. Fracture Toughness Tests (EML-82)		EML-A.2 Be. Property Tests (EML-82)	
EML-A.3 Forward End Seal Test (EML-78)			
EML-C.1 Tungsten Protection Cup Test (EML-69)		EML-C.1 A6 Prerequisite Support Block Tests (EML-69)	
EML-D.5 Lateral Support System Static Tests (EML-86)		EML-D.5 Lateral Support System Leakage Tests (EML-86)	
EML-E.2 Friction Coating and Wear Tests (EML-75)		EML-E.2 Continue Friction Tests (EML-75)	
EML-E.3 Core Impedance Model (EML-60)		EML-E.3 Additional Tests of Core Seal Shapes - (EML-60)	
Pinhole Tests (EML-60)			
General Development			
EML-A.1 Insulating Cylinder Fastener Test (EML-82)		EML-A.1 Development Tests of Insulating Cylinder Fastener Test (EML-82)	
EML-B.1 Fuel Element Porosity Tests at Temps.(EML-66)		EML-B.1 Porosity Tests (EML-66)	
	Fuel Element Tension Tests at R. Temp.(EML-66)		
EML-E.1 Core Wrapper Tests (EML-93)		EML-E.1 Thermal Cycling of Core Periphery with Pyrofoil Wrapper (EML-93)	
EML-H.2 Fuel Element Acoustic Tests (EML-95)		EML-H.2 Acoustic Tests (EML-95)	
Facilities			
EML	Bundling Furnace Delivery	EML	Friction Furnace Delivery

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XE TESTS

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FFL-1.a Single Cluster Development Tests

A total of eight cluster tests were completed during the period October 1, 1966 through November 15, 1966. There are nine more tests scheduled in this series.

There were three exit gas thermocouple tests initiated during the period. The first test was aborted when a rupture disc in the inlet helium line failed during start-up.

The second test, using a new thermocouple, was initiated and operated for a period of 21 minutes at a temperature of 4383°R . Upon disassembly it was found that the protection cup and inconel collar had melted.

The third test, using a modified design of the flow impedance ring inside the protection cup, was successfully conducted. The test was conducted in two cycles. The first cycle was operated for a period of 20 minutes at a temperature of 4280°R . The second cycle was operated for a period of 17 minutes at a temperature of 4350°R . The thermocouple performed adequately throughout the test, responding to all changes in power input or flow rate with a corresponding temperature change. The total operating time for both cycles, including all ramps, was approximately 60 minutes. The assembly was found to be undamaged after the test.

EML-H.1 XECF Resonant Survey (EML-55)

More frequent negotiations have been established with Aerojet-General Corporation to ensure the coordination of the XECF Resonant Survey Test. Reference 35 of XECF Test Plan, Vibration Survey of XECF in ETS-1, has been reviewed and approved. The Resonant Survey is presently scheduled to be performed at the end of the XECF tests. The trailer-type vehicle containing the instrumentation will be ready for this test. Also, shaker equipment will be shipped independently to the Nevada Site when needed.

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NRX-A6 Tests

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FFL-1. a Single Cluster Development Tests

The NRX-A6 skirtless block with coated ATJ protection cup was successfully tested for a total time of 65 minutes. The test was conducted in three cycles.

The first cycle was operated for a period of 17 minutes at 4280°R. Upon disassembly, it was found that the cup was welded to the block. The assembly was rebuilt, using the same block and cup, and was tested for an additional 27 minutes at a temperature of 4280°R. The model was again disassembled and welding between the block and the elements was observed. This welding caused some loss of coating on the leading face of the block. The assembly was again rebuilt, using the same block and cup, and tested for an additional 21 minutes at 4280°R. The support system performed adequately throughout the test, even though several large areas of coating had been lost during disassembly of the cluster following the second cycle. Post-test inspection of the block showed, that where the coating had remained intact there was no damage. There was some material loss in the areas where coating had been lost.

A skirtless block with a tungsten cup was tested for a period of 10 minutes at 4280°R. Furnace failure during the second cycle caused the test to be terminated. Coating loss over substantial areas of the block did not make further testing feasible.

Future plans in this area calls for 60 minute tests on a skirtless block with a tungsten cup and a skirtless block with a NbC cup. The exit gas thermocouple is also scheduled for a 60 minute test.

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

There were 188 tests conducted in support of the Fuel Assessment Program during the period October 1, 1966 through November 15, 1966. More testing is planned in the future.

FFL-2. a Filler Strip Corrosion Tests

The assembly of the seventh filler strip test model with the grafoil wrapper has been completed. This model is scheduled to be tested in December, 1966.

FFL-6. a NRX-A6 360° Shield Purge Flow Tests

Tests were initiated on a model simulating the NRX-A6 reactor with the 360° shield, Figure 1. These tests are being conducted to determine the best method of sweeping the annulus, between the reactor and the shield, free of any flammable gas mixture and also to ascertain the conditions that might produce atmospheric ingestion. A number of purge flow manifolds have been proposed and have been tested.

A variety of test methods have been employed as follows:

1. Static pressure measurements located axially along the shield at 120° circumferential locations.
2. Thread streamers placed axially and circumferentially on the shield and on the reactor, radially on the model base (representing the privy roof), and around the impedance collar annuli.
3. Smoke injection externally to indicate atmospheric ingestion.
4. Smoke injection locally around and axially along the shield, around and along the reactor (including the external periphery of the nozzle throat), and at the reactor base.
5. Smoke injection directly into the manifolds.

In addition to being quite hazardous, the smoke injection has proved to be unsatisfactory due to the turbulence of the flow.

No reliable results have been determined with the shield static pressure measurements; however, indicative flow patterns have been observed with the thread streamers. The streamers indicated that ingestion occurs when the

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FIGURE 1

NRX-A6 360° SHIELD/REACTOR MODEL

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instrumentation coolant duct and/or the angular flow producing manifold are in operation. It appeared that any of the other manifold combinations produced no flow ingestion and that they satisfactorily swept the reactor/shield annulus. Refinements to the streamer technique and additional attempts to utilize smoke injection will be made in an attempt to determine the flow patterns within the annulus as accurately as possible.

An attempt to produce an exhaust plume for the nozzle by inserting a plug in the nozzle is forthcoming. The nozzle flow may indicate other problem areas. Testing should be completed near the middle of December.

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EML-A.2 Reflector Material Tests (EML-82)

A fracture toughness test program was initiated to support Reactor Design efforts in application of fracture mechanics to their analysis of the reflector since there was insufficient information available to determine the behavior of a crack induced by a sudden stress. Also, it was not clearly understood whether the crack would arrest within the material or propagate throughout the reflector causing a loss of structural integrity of the component.

A loading fixture was developed and used to test a double cantilever beam type beryllium specimen. An omega type compliance gage as shown in Figure 2 was designed and used in the test setup. Testing was conducted at ambient temperature and then at -320°F using liquid nitrogen.

The results at ambient and -320°F indicated that no unstable crack growth occurred and that crack arrest can be expected. The specimens tested sustained more than ten crack arrests before complete separation or fracture occurred. Figure 3 shows a typical plot of load versus deflection and the points of crack arrest.

The critical strain energy release rate G_{IC} , varies from an average of 1.9 in.-lb/in. at -320°F to 5.3 at ambient temperature. Additional testing will be performed at an intermediate temperature.

EML-A.3 Forward End Seal (EML-78)

A test of an NRX-A6 reactor grade seal ring was performed to establish the accuracy of the analytical procedure that is to be used in calculating seal stresses for loads anticipated to occur during reactor operation. Loads required to deflect the seal and resulting stresses were measured at room temperature for various axial displacements.

The test was performed by bolting the seal to a rigid test rig that could be axially displaced relative to a stationary ring that engaged the outer periphery

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FIGURE 2

OMEGA COMPLIANCE GAGE IN POSITION

FIGURE 3

TYPICAL DEFLECTION vs LOAD FOR SPECIMEN

of the seal. Accurately controlled relative deflection between the inner and outer periphery of the seal was obtained by displacing the movable test rig relative to the stationary ring by three jacks attached between the rig and ring. Integral with the jacks were load cells that determined the loads required to deflect the seal. The test assembly is shown in Figure 4.

One complete axial displacement cycle was made by deflecting the seal in 0.025 inch increments until a total displacement of 0.400 inches was obtained. Return to initial position of the seal was done in 0.100 inch increments. The initial test displacement position of the seal was established at an axial distance of 0.675 inches between the bolting surface of the inner periphery of the seal to the contact surface of the outer periphery of the seal. This position is approximately 0.100 inches greater than the nominal reactor assembled position of the seal. Measurements of the load required to deflect the seal and strains were recorded at each displacement increment. Twelve additional displacement cycles were performed to obtain effects of repeated loading on the seal.

The experimental maximum radial stress, circumferential stresses and loads used to displace the seal are presented in Figure 5. There was good agreement between calculated and experimental data.

EML-C.1 Tungsten Protection Cup Tests (EML-69)

At the last meeting it was reported that an extruded tungsten cup of thoriated G. E. material had small cracks after one hour's exposure at 4500°R. Metallography had not been completed at that time but was in process. This work is now complete and the findings have shown that the surface cracks penetrated only into the carbide layer of the cup. The photographs of the sections are included as Figures 5 to 7. The main points to be made here are that:

1. Clearance between the inverted cup and the support block was still ample. Carbiding caused by the furnace atmosphere is evident by the light line shown on Figure 5.

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FIGURE 4
FORWARD END SEAL TEST ASSEMBLY

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PHOTOMICROGRAPH OF INVERTED CUP
SHOWING CLEARANCE. NOTE THE
CARBIDE PENETRATION INDICATED BY
THE LIGHT LINE ON THE TUNGSTEN
SECTION (50X magnification).

MICROPHOTOGRAPH OF
SECTIONED SUPPORT BLOCK
AND TUNGSTEN CUP

FIGURE 5

FIGURE 5a
SEAL RADIAL STRESS-
DEFLECTION CURVE

FIGURE 5b
SEAL CIRCUMFERENTIAL STRESS-
DEFLECTION CURVE

FIGURE 5c
LOAD-DEFLECTION
CURVE

2. Figure 6 shows that the interface between the two cups was firmly welded so that the parting line cannot be observed even at 50X magnification. Heavy carbiding is evident at the top of the photograph where the tungsten was in contact with the pyrographite insulating washer. Note also that a very small carbide layer is present where the tungsten was in contact with the niobium carbide of the support washer.
3. Surface cracks observed on the tungsten cups in Figures 6 and 7 extend only through the carbide layer and do not penetrate into the parent tungsten material.

During the last period the tungsten cup of G.E. thoriated extruded material was run with an 800 lb loading for one hour at 4500°R to determine the amount of creep. Under loading and temperature there is a tendency for the smaller tungsten cup to deform with the rim loading inward and the bottom bending slightly. Similarly, the bottom of the top cup deflects permanently under the applied load. The weld between the two cups holds firmly under this deformation. The tests showed an increase in diameter of 8-1/2 mils for the smaller cup and 7-3/10 mils for the larger cup. The height of the combination was increased 7 mils over the before-test values.

Two ultimate load tests of G.E. thoriated tungsten cups were also completed at 4500°R. The first of these showed a drop off of load at 2560 lb. This test resulted in a failure in the insulating cup. The second tungsten cup failed at 3400 lb with a slow yielding before final failure. In this test the ATJ support washer had crushed and expanded the smaller of the two tungsten cups to failure. The weld at the interface between the two tungsten cups held firm so that deformation of the smaller cup resulted in a fracture of the larger. In failing both of these tungsten cups the process differs from graphite part failures in that considerable yielding is observed before total failure occurs. Metallographic examination of both of these cups is in process.

INNER EDGE (NEAR CENTER HOLE OF
INTERFACE BETWEEN TUNGSTEN CUPS.
NOTE THAT THE WELD HAS OBLITERATED
THE PARTING LINE. HEAVY CARBIDING
IS EVIDENT AT THE TOP OF THE SECTION
WHERE THE TUNGSTEN WAS IN CONTACT
WITH THE INSULATING WASHER
(50X magnification)

OUTER EDGE OF INTERFACE BETWEEN
THE TUNGSTEN BACK-TO-BACK CUPS
(50 X magnification)

FIGURE 6

TWO VIEWS OF INTERFACE BETWEEN THE BACK-TO-BACK TUNGSTEN CUPS. THE INSULATING WASHER WAS IN CONTACT WITH THE TOP AND RESULTED IN HEAVY CARBIDING. NOTE THAT NO CARBIDING IS PRESENT AT THE WELD JOINT SHOWN IN THE PHOTO ON THE LEFT (50X magnification).

FIGURE 7

The G.E. thoriated tungsten material, used in the cup tests described, is not considered a candidate for the reactor because of the dispersion of the thoriated material. A prime alternate candidate for the NRX-A6 is a vapor-deposited cup. The only specimens available for test during the last period were the G.E. thoriated cups and it was felt that the data on behavior and load capability would still be of value.

EML-D.5 Lateral Support System Tests (EML-86)

A static test was performed on a simulated NRX-A6 lateral support system. A fixture was used to apply radial loads to a solid graphite disc which represented a nine-inch length of the core. Four rows of lateral support reactor grade hardware consisting of seal segments, insulating segments, plunger pins, latches, sleeves with seals, springs, and retaining caps were installed in an aluminum reflector ring. Since the squeeze rings and "C" rings are needed for future leakage tests, they were not assembled at this time.

Evaluation of the data indicates that the radial spring rate at the geometrical center of the core was 7,100 lb/in. while the pitching spring rate about the horizontal axis was 2,100 lb/degree. After six loading cycles, the pitching motion had resulted in the core moving axially approximately 3/8 inch. The dead zone, that is the limits at which the core remains after being displaced, was found to be ± 0.112 inch from the center position.

Inspection of the components after disassembly showed normal polishing of the mating surfaces between the plunger pins and seal segments. The utilization of Reactor Assembly personnel in assembling the hardware resulted in obtaining information required for modifying special tooling and procedures to be used for the NRX-A6 build.

The test components were re-assembled and the pitching motion of the core was restrained by load cells mounted perpendicular to the face of the solid graphite disc. The location of the load cells above and below the horizontal

centerline of the core was dependent on the direction of the moment required to resist the pitching. A typical complete cycle of radial force versus displacement is shown in Figure 8. The spring rate during the initial translation of the core downward from A to B is relatively stiff with an average spring rate of 20,000 lb per inch. Over this displacement the plunger pins at 90° from the loading direction are active until friction is overcome and the seals slip. From B to C the spring rate is seen to be 7,400 lb per inch. The downward motion of the core tends to unload the springs at the top which in turn reduce the developed friction forces between the core and inner seal segment. The area concerned is shown in Figure 9. At point C, the slipping of the core and inner seal segment are such as to reduce the number of active lateral support springs and, therefore, the spring rate reduces to 3,600 lb per inch. Reversing the loading to translate the core upward results in a similar stiff spring rate as shown before from A to B. At point F the axial load cell was unloaded causing a shifting of forces.

EML-E.1 Pyrofoil Tear Test (EML-68)

When pyrofoil is used as a wrapper on the core periphery, analysis shows that bundling pressures will be increased because of the higher differential pressure. There was also concern that during cooldown the differences in cooling rate between the adjacent filler strips could result in tearing of the pyrofoil. During differential expansion of the filler strips it is possible to get as much as 0.040 inch displacement between adjacent filler strips. A series of tests was conducted using six layers of 0.005 inch thick pyrofoil to determine the tear characteristics of the foil against uncoated filler strip material. The tests were run at room temperature employing lateral mechanical loads (bundling plus differential gas pressures) simulating; 100, 280, and 420 psi at 4400°R . Under these bundling loads opposite filler strips were displaced 0.040 inch to determine whether the foil would tear. The test specimens consisted of seven blocks of simulated filler strips on opposite sides of the six layers of pyrofoil. In setting up the test, two

FIGURE 8
 DISPLACEMENT CYCLE

FIGURE 9
 LATERAL SUPPORT SYSTEM SECTION

filler strips on opposite sides of the foil were raised above their neighbors so that after bundling pressure was applied they could be displaced 0.040 inch. After the test, all Grafoil specimens were in excellent condition and showed only a slight burnished area as shown in Figure 10.

Friction tests, which will be described later, showed that the worst possible coefficient of friction would be obtained when Grafoil is used in contact with niobium carbide coated filler strips. Two additional tests were then conducted to simulate this condition. In this test one layer of Grafoil was cemented to filler strips to simulate a lockup between the foil and filler strips at 4400°R. When the opposite filler strips were displaced, the foil sheared in a series of 45° lines approximately 0.060 inch in length along the complete length of the mating line of adjacent filler strips. The foil was not separated into two pieces at these shear areas; however, pinholes through the material were present. The remaining five layers were in good condition as shown on Figure 11. The cemented portion is shown at the right of the photograph. Note that the other five layers of pyrofoil are essentially undamaged.

EML-E.2 Friction Test of Reactor Components (EML-75)

Tests of pyrofoil in combination with core periphery material specimens were performed to determine the friction and wear that would occur during repeated reactor test runs of ten minute duration each. Test conditions and results are summarized in Table III.

EML-E.3 Core Effective Gap Tests (EML-60)

A. Aft End Flow Impedance Seal Evaluation

The preliminary flow tests were run on a 9-1/2 inch dia. 7 cluster model core in the test vessel shown in Figure 12. The flow was restricted to the central seven clusters. The average gap as a function of bundling pressure for the model core is shown in Figure 13. The helium flow rate for a ΔP of 35 psi across a

FIGURE 10

GRAFOIL SPECIMEN FOLLOWING 0.040 FILLER STRIP DISPLACEMENT
SIMULATED LATERAL LOADING OF 100 Psi

FIGURE 11

SIMULATED COATED FILLER STRIP TEST SPECIMENS FOLLOWING
0.040 FILLER STRIP DISPLACEMENT SIMULATED LATERAL LOADING OF 100 PSI

TABLE III

Specimen	Test Temp. °R	No. Cycles	Contact Pressure Psi	Gas Environment			Breakaway Force *	Results
				To Temp.	At Temp.	Cool-down		
Pyrofoil (0.010" thick) between Pyrotile & NbC Coated Filler Strip	4400	3	93	8 SCFH	H ₂		.15	Pyrotile slipped on foil. No significant interface damage occurred between pyrotile and foil. Foil adhered to NbC coated specimen.
Pyrofoil (2 layers 0.005" thick) between Pyrotile & NbC Coated Filler Strip	4400	3	93	8 SCFH	H ₂		.15	Interface slippage occurred between pyrotile and foil and between foil and foil. No significant damage occurred between interfaces that slipped. One layer of foil adhered to NbC coated specimen.
Pyrofoil (2 layers 0.005" thick) between Pyrotile & NbC Coated Filler Strip	3300	3	93	1.7 SCFH H ₂	1.34 SCFH H ₂ & .34 SCFH CH ₄	1.7 SCFH H ₂	Increased each cycle from 0.5 to 0.8	Interface slippage occurred initially between pyrotile and foil and between foil and foil. No significant damage occurred between foil and foil interface. One foil adhered to pyrotile specimen and one foil adhered to NbC coated specimen.

*Breakaway force is expressed as a ratio of the force required to slide one specimen relative to the other to the force that held the specimens in contact.

Table continued

Specimen	Test Temp. °R	No. Cycles	Contact Pressure Psi	Gas Environment			Breakaway Force *	Results
				To Temp.	At Temp.	Cool- down		
Pyrofoil (0.005" thick) & uncoated Filler Strip	4400	5	93	8 SCFH	H ₂		0.2 (first cycle) 0.12 (subsequent cycles)	No significant visual damage to uncoated filler strip and pyrofoil.
Pyrofoil (0.005" thick) and Pyrotile	3300	5	10	8 SCFH	H ₂		0.07 (first cycle) 0.03 (subsequent cycles)	No significant visual damage to pyrotile and pyrofoil.
Pyrofoil (0.005" thick) and uncoated Filler Strip	3300	5	93	8 SCFH	H ₂		0.10	No significant visual damage to uncoated filler strip & pyrofoil.
Pyrofoil (0.005" thick) & uncoated Filler Strip	3300	1-1/2	93	1.34 SCFH H ₂	1.34 SCFH H ₂ & .34 SCFH CH ₄	1.34 SCFH H ₂	0.65	Specimens were held in contact and at test temp. for the 10 min. test run, and then motion cycle was performed. Pyrofoil partially adhered to uncoated filler strip and slight separation of foil layers resulted.
Pyrofoil (0.005" thick) & NbC Coated Filler Strip	4400	1	93	8 SCFH	H ₂		1.0	On initial motion cycle pyrofoil adhered to NbC coated surface and separation of foil layers occurred.

* Breakaway force is expressed as a ratio of the force required to slide one specimen relative to the other to the force that held the specimens in contact.

AFT END IMPEDANCE TEST FIXTURE

FIGURE 12

FIGURE 13
AVERAGE GAP AND COMPACTION IN 7-1/2
DIAMETER CORE AS FUNCTION OF BUNDLING PRESSURE

plain core without sleeves varied from approximately 0.3 lb per hour at 60 psi average bundling pressure to two lb per hour at 20 psi bundling. These values when compared to the flow rates to be measured on an aft end sleeve core will provide a measure of the flow impedance provided by the sleeve.

To obtain a better evaluation of the bundling pressure on the model, core pressure probes are being installed at three axial and three radial stations. These will measure the interelement pressure distribution.

A close tolerance element core and a sleeved core are now being machined and will be tested during the next month.

B. Pinhole Tests

Results of a recent radial flow pinhole test were compared to a previous similar test and axial flow pinhole tests.

The following is a comparison of the radial flow pinhole tests performed on August 10, 1966, and October 14, 1966. In these tests 25 mil diameter pinholes were located ten inches and five inches from the center of the core, respectively. The radial pressure drop was 35 psig.

Flow measurements for both these tests agree well and are summarized on the following table.

<u>Test</u>	<u>Core Total Flow (lb/sec)</u>	<u>Pinhole Inflow (lb/sec x 10⁻⁴)</u>	<u>Pinhole Radial Location</u>
8-10-66	.0055 - .0080	.51 - .89	10"
10-14-66	.0070 - .0082	.56 - 1.00	5"

Pressure profile perturbations were measured by pressure transducers immediately adjacent to the pinhole in the former test. In the latter test the same transducers did not indicate any perturbation. The rather steep gas velocity gradient near the core center may be the cause of this discrepancy. Pressure probes approximately 1 to 1.5 inches away from the pinholes did not indicate perturbations in either test.

Comparison of axial and radial flow pinhole measurements are summarized below.

<u>Test</u>	<u>Core ΔP (psig)</u>	<u>Head or Peripheral Pressure (psig)</u>	<u>Total Flow (lb / sec.)</u>
Axial Flow	35	100	.033
Radial Flow	35	100	.0070

Axial flow pressure profile measurements show a definite perturbation at pinholes.

In addition pressure perturbations were measured at 1.5 inches from pinholes. No such perturbations were measured during radial flow tests with similar pinhole pressure drops.

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FFL-5. b Interstitial Corrosion Tests

Since September 27, 1966, seven tests studying the effects of mass flow rate on the corrosion reaction in narrow slots have been conducted. Three of these tests were conducted at 50% reduction in normal flow (4.6×10^{-5} lb/sec H_2) and inlet pressures of 350, 50, and 100 psig, respectively.

Four of these tests were conducted at a factor of 2, increase in normal flow and inlet pressures of 350, 100, 300, and 250 psig, respectively. Figure 14 shows this data plotted with data obtained from past tests. The curve shows corrosion rate in gms/in² sec as a function of inlet pressure in psig. The curve family is established by changes in mass flow rate. The trend established by the reduced flow shows a general reduction in corrosion rate which increases with pressure. At the lower pressure range, the corrosion rate approaches that established by the data, which is considered the established norm.

The trend established by the increased flows show a general increase in corrosion rate which increases with pressure. Points at the low pressure range could not be obtained due to a choking condition which made it impossible to establish the required flow rate at the set pressure and temperature.

In addition to the slot corrosion tests, two pyrofoil corrosion tests were conducted which simulated the A-6 wrapper in contact with a filler strip gap. Figures 15 and 16 show the general configuration of the hardware. The first test was conducted at 350 psig inlet pressure, 4000°R material temperatures, 4.6×10^{-5} lb/sec hydrogen flow and was scheduled to operate for 60 minutes. The test was aborted at the 30 minute mark due to unstable temperature readings. Disassembly of the fixture showed the high temperature level to be quite severe on the hardware in that the outer carbided surfaces of the moly can melted.

The results of this test showed slight corrosion on the pyrofoil in the form of a black line on its surface, shown on Figure 17. Examination of the measurement

Test Conditions

Inlet Pressure - As Shown

Material Temperature - 3500°R

Flow Rate:

○ - 4.5×10^{-5} lb/sec

□ - 2.3×10^{-5} lb/sec

◇ - 9.2×10^{-5} lb/sec

FIGURE 14

INTERSTITIAL CORROSION STUDIES

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FIGURE 15
GENERAL PYROFOIL CORROSION TEST HARDWARE

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FIGURE 16

GENERAL PYROFOIL CORROSION TEST HARDWARE

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FIGURE 17
FIRST PYROFOIL CORROSION TEST 4000°R, 30 MINUTES

data showed that the pyrofoil swelled 1.5 mils which would tend to separate the halves of the fixture; thus making the aft end seal ineffective in reducing the hydrogen flow through the filler slot.

A second test was conducted at a recommended material temperature of 3500°R, using stabilized pyrofoil, for a period of 30 minutes. The results of this test showed more corrosion on the pyrofoil because hydrogen was directed to the proper areas. Figure 18 shows corrosion in the filler gap and on the inlet edge and surface of the pyrofoil. Photomicrographs in support of figure 18 were used to measure corrosion areas on the pyrofoil and the corrosion profile of the filler strip gap. These measurements were used to calculate corrosion rates.

FFL-5. c Reactor Graphite Component Permeability Tests

Permeability tests were conducted during this period in the High Temperature Instrumentation Qualification Furnace. Tests were conducted on an unfueled element with graphite plugs cemented in the outlet end. It was realized prior to testing that the seal was less than satisfactory but it was decided to proceed until more sophisticated seals could be obtained. The first series of tests were conducted at ambient temperature, first with helium gas and then hydrogen gas, at a pressure of approximately 620 psia and pressure differences of 5 to 90 psid. Figure 19 presents the results of this test. The good correlation between the helium gas and hydrogen gas is indicative of a strong flow dependence upon viscosity and laminar flow.

A second series of tests were conducted using helium gas at a pressure of approximately 620 psia and pressure differences of 5 to 90 psid. The initial test was conducted at ambient temperature and yielded the curve 1 on Figure 20. The temperature of the specimen was increased with a maximum temperature at station 45 of 2500°R and a second test was conducted. As the pressure differential was

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FIGURE 18

SECOND PYROFOIL TEST, 3500°R, 30 MINUTES

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FIGURE 19

WEIGHT FLOW VS D'ARCY PARAMETER, BUILD 1 RUN 1

FIGURE 20

WEIGHT FLOW VS D'ARCY PARAMETER, BUILD 2 RUNS 1 AND 2

increased, the flow rate increased along curve 2 of Figure 20. Upon reaching 90 psid pressure differential, a "retreat" was made and the third curve was obtained. The hysteresis indicated that a leak had developed during testing. The specimen was cooled to ambient temperature and another test was made at ambient temperature yielding curve 4 of Figure 20. It should be noted that good agreement exists between curves 3 and 4 indicating a stabilization of the leak.

Inherent in the testing of a long test piece with a severe axial temperature distribution, is the difficulty for correlation purposes of choosing an "effective" temperature level, which so heavily weights the D'arcy parameter $\frac{P_1^2 - P_2^2}{\mu RT}$, along with the viscosity μ .

Additional testing in this area will be conducted in the next period.

EML-A.1 Reflector Insulating Cylinder Fastener-Static Load Development Test (EML-82)

A static load test of an NRX-A6 reflector insulating cylinder fastener was made. This test was performed by mounting the test specimen, which consisted of one fastener assembled with a representative section of the insulating cylinder, in a standard testing machine, and applying a tensile load.

A linear ratio between the load and deflection of 75,000 lb/inch spring rate was determined for loads to 600 lb. Significant increase in the deflection rate occurred for loads to 1330 lb, where failure of the assembly occurred.

Post-test inspection revealed that buckling of the insulating cylinder sheet and slight crushing of the fastener occurred at the area of contact between the fastener and sheet.

EML-B.1 Fuel Element Development and Evaluation (EML-66)

A. Fuel Element Porosity Tests at Temperature

During the last period two porosity tests at high temperature were completed. The first of these was done on a short length (ten inch long element) assembled in the arrangement shown in Figure 21. The entire ten inch length of element was placed in the furnace at uniform temperature. The fixturing shown in the figure consisted of low-permeability ZTA graphite with pyrofoil seals. This test showed that flows through the element were so low that even with the smallest flow meters available data could not be recorded above 3000°R even though an unfueled, uncoated element was used in the test. It was necessary then to assemble a full length element for these fixtures to take advantage of the greater total flows available with the increased length. A uniform heating-zone heating element was installed in the 6 x 54 furnace and, using the identical fixtures shown in the photograph, the assembly was placed in the furnace so that a full length element could be tested. This element was tested at room temperature, 2000°R, 3000°R, 4000°R and 4500°R with differential pressures of 10, 20, 30, 40, 50, 60

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FIGURE 21

FUEL ELEMENT POROSITY TEST SETUP
EML-66

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and 70 psi. In these tests, the higher pressure is maintained in the bores of the element. The data is shown on the curve of Figure 22 for fueled element (coated) No. 99-26636. In presenting this data it was assumed that gas temperature was equal to the element temperature due to the small flow rates involved. It must be understood that this data is preliminary and was completed just prior to this meeting. Additional data will be presented at the next SNPO meeting.

B. Fuel Element Tension Tests at Room Temperature

During the last period the tension tests on fueled elements were completed. These tests were conducted using the bundling fixture and technique previously described. The test specimens used for this work were cut at stations 10, 20, 30 and 40 and assembled to the test fixture so that maximum strain was obtained at the six inches in the center of the element. Incremental weight loss data on corrosion tests shows that maximum weight loss occurs about station 20 for these elements. To obtain information on failure strain of elements at this point three elements were sectioned at stations 15 and 25 so that station 20 was at the center of the test specimen. This placed the most severe region at the midpoint of the specimen where the transmitted strain is more uniform with less slip than could occur near the ends of the specimen.

One of these test specimens, S/N 99-74513, had a pinhole at station 21.38. This is shown in the Figure 23. Under tensile loads this specimen failed at a strain of 1830×10^{-6} in./in. directly through the pinhole. A second failure occurred at station 19 in the same specimen at a strain of approximately 2680×10^{-6} in./in. The specimen is shown in Figure 24. With the pinhole evident on the face marked 21, the face marked 19 on the figure has the appearance of another pinhole that has not yet broken through the surface.

In reviewing the results of these tensile tests it has been impossible to establish a change in failure strain as a function of time in the corrosion test.

FIGURE 22

FIGURE 23

TEN INCH SECTION REMOVED FROM ELEMENT SUBJECTED TO A 40 MINUTE CORROSION TEST. NOTE PINHOLE IN SURFACE AT STA. 21-3/8.

FIGURE 24

SPECIMEN AFTER REMOVAL FROM TEST APPARATUS

Table IV summarizes the results for both WANL and Oak Ridge elements for zero time and twenty minute elements used in the tests.

EML-E.1 Core Wrapper Tests (EML-93)

The strain capability of the pyrofoil sleeve material at reactor operating temperature is being studied further by the differential expansion method which was discussed in the last monthly report. A graphite log with at least 50 percent higher expansion coefficient was machined and is scheduled for heating in the next period.

Test to obtain the relationship between foil compaction and load are underway at this time. This information is needed to establish tolerances required in fabrication of the parts. Initial tests indicate loads greater than 20 psi are required to achieve a compaction of 0.0002 inch.

EML-H.2 Component Acoustic Tests (EML-95)

A second acoustic test of fueled elements was planned. In summary, both furnace corroded and non-corroded elements will be exposed to an acoustic environment within a reverberation chamber. Test evaluation techniques to be performed before and after acoustic test include weight measurements, porosity measurements, channel blowdown and bore replications.

Test evaluation of nonfueled element segments (Acoustic Test No. 1) in the last month consisted of a brief micrographic study of the cold region segments. Micrographic study in the cold region was found to be very difficult with small probability of success. No conclusive results can be reported.

Each of these specimens was tested in a 64 cubic foot reverberation chamber at measured sound pressure levels from 149 db to 157 db. The measured sound spectrum approximated that specified in MS 810 A, Method 515. Test exposure times were varied between 15 and 60 minutes.

TABLE IV
FRACTURE STRAIN vs CORROSION TIME

OAK RIDGE ELEMENTS		WANL ELEMENTS	
FRACTURE STRAIN	TIME IN CORROSION TEST	FRACTURE STRAIN	TIME IN CORROSION TEST
2360 μ in./in. (max.) 2260 μ in./in. (min)	0 0	2560 μ in./in.(max) 2080 μ in./in.(min)	0 0
2330 μ in./in. (max) 2000 μ in./in. (min)	20 min 20 min	2420 μ in./in.(max) 1665 μ in./in.(min)	20 min 20 min
2050 μ in./in. (max) 1830 μ in./in. (min)	40 min 40 min	No 40-min WANL elements available for test	

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Installation of the guard heater power supply has been initiated. This power supply will make it possible to reach higher fuel element temperatures and will also increase the range of the temperature profile changes.

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