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February, 1966

Westinghouse Astronuclear Laboratory

NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW MEETING
HELD WITH SNPO AT WANL ON JANUARY 28, 1966
(Title Unclassified)

MASTER

TME 1376

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(38)

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Westinghouse Electric Corporation
Astronuclear Laboratory
P. O. Box 10864
Pittsburgh, Pennsylvania 15236

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W. J. Rowan
W. J. Rowan, Manager
Engineering Mechanics

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E. A. DeZubay
E. A. DeZubay, Manager
Fluid Flow Laboratory

INFORMATION CATEGORY
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Notes of Monthly Development Test Program Review Meeting

held with SNPO at WANL on January 28, 1966

Attendees:

Bifano, N. J.	WANL	Olinger, J. S.	WANL
Blinn, M. B.	WANL	Ramp, R. L.	WANL
DeZubay, E. A.	WANL	Retallick, F. D.	WANL
Fix, H. J.	WANL	Rowan, W. J.	WANL
Havener, W. J.	WANL	Saccocio, R. M.	WANL
Kalvin, G.	SNPO-C	Schreiber, J. J.	WANL
Kanter, I. E.	WANL	Tauch, F. G.	WANL
Kelly, V. G.	WANL	Thompson, D. C.	WANL
Larson, L.	AGC	Watjen, E. A.	WANL
Murphy, H.	SNPO-C		

The Monthly Development Test Program Review Meeting was held on January 28, 1966, at WANL. Brief summaries of the tests performed and planned by the Engineering Mechanics and Fluid Flow Laboratories were distributed to those in attendance. These summaries are shown in Tables I and II.

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

TABLE I

PERFORMED THIS PERIOD

PLANNED NEXT PERIOD

Tests for NRX-A4

EML-69 - NRX-A4 Support Blocks Cracked for Corrosion Tests

Tests for NRX-A5

EML-61 - Hollow Instr. Tie Rod Tests
 EML-69 - Support Block and Washer Tests
 EML-75 - Friction Tests (Filler Strip-Pyrotile)
 EML-76 - Hardware Static & Dynamic Test (Seal Block, Purge Port, C. D. Spring Tests)
 EML-86 - Lateral Support System Tests
 EML-88 - Control Drum Bow Tests
 EML-94 - Buffer Periphery Test (Block Cocking Tests)

EML-69 - Support Block Tests
 EML-75 - Friction Tests
 EML-76 - Alternate Seal Block Tests
 EML-94 - Radial Expansion Tests, Keyed Element Periphery Test

Tests for NRX-A6

EML-60 - Core Effective Gap Test (Pinhole Tests)
 EML-69 - Support Block and Cup Tests
 EML-70 - Blockless Cluster Tests (Skirtless Tab Tip)
 EML-86 - Lateral Support System (Design & Procurement)
 EML-92 - Contact Resistance (ZTA - Be)

EML-60 - Element Pinhole Test and Rearranged Core
 EML-69 - Support Block Tests
 EML-70 - Blockless Cluster Tests
 EML-86 - Lateral Support System (Procurement)
 EML-92 - ZTA and Be Coefficient Evaluation

General Development

EML-55 - Resonance Survey Planning
 EML-61 - Graphite Tie Rod Tests
 EML-82 - Outer Reflector Sector Tests (Leakage & Strain)

EML-55 - Resonance Survey
 EML-60 - Fuel Element Porosity Tests
 EML-82 - Be Strain Cycling Tests

Facilities

Vacuum Test Equipment
 High Pressure Furnace
 Lateral Support System Evaluation Facility

TABLE II

PERFORMED THIS PERIOD	PLANNED NEXT PERIOD
Tests for NRX-A4	
HHT-2 - NRX-A4 Fuel Element Simulation	Oscillating Temperatures
HHT-4 - NRX-A4 Cracked Block Life Test (20 Minutes)	Continue to 40 Minutes
Cluster with NRX-A3 Block (13 Minutes)	
Aluminum Radiation Shield Tests	Activity Concluded
Tests for NRX-A5	
HHT-1 - Quality Control	
HHT-2 - Life Tests and Single Hole	
HHT-4 - NRX-A5 Block Life Test (40 Minutes)	NRX-A5 Cracked Block
HHT-7 - None	Build 4 Test 2
FFL-18 - Single Seal	Conclude Flow Visualization
FFL-20	Tests Initiated
FFL-21 - Support Blocks	No Further Activity
FFL-23 - Nozzle End Seal	Test Four Seals
FFL-27 - Five Instrument Blocks Tested	Alternate Design
Tests for NRX-A6	
HHT-2 - Life Tests	Life Tests
FFL-18	Seal Test With A-6 Scarf Joints
General Development	
HHT-2 - Plugged Peripheral Holes	Orificed Channels for Pinholing
Direct Gas Inlet	Pinholing by Direct Gas Inlet
Voltage Probes	
HHT-6 - Long Gap Tests	Preempted by HHT-2 and HHT-4
Isothermal	
HHT-7 - Hot Buffer (1/2 ZrC + 1/2 No Coating)	None

TABLE II (CONTINUED)

PERFORMED THIS PERIOD	PLANNED NEXT PERIOD
Facilities	
WANHES Vaporizer	Qualification Tests
Large Site Vaporizer - Installation Complete	Completion of Installation
Thermocouple Furnace	No Activity
New A-2 Furnace	

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NRX-A4 TESTS

EML-69 Support Block Mechanical and Thermal Testing

The work performed during this period was to provide services in the form of preparing blocks for testing conducted by other departments. This includes providing support blocks that have been cracked in the furnace at loads expected to produce fine cracks that would simulate the effects observed on the NRX-A3 blocks. An NRX-A4 support block was cracked at 4300°R under 3000 pound loading. This block was then forwarded to Fluid Flow Laboratory for additional testing.

HHT-2 Single Element Process Development and Evaluation Tests

Three NRX-A4 fuel elements were hydrogen corrosion tested to simulate the NRX-A4 test plan. Two of the elements were tested to simulate the nominal expected temperatures and the third element was tested to simulate the nominal maximum temperatures expected.

The incremental weight losses and electrical resistances were as expected and from the information derived from these tests the NRX-A4 elements should perform as expected.

A special test is planned to determine if oscillation in temperatures of 470°F can be achieved at particular holds in the NRX-A4 simulation.

HHT-4 Single Cluster Development Test

The post-test A-3 support block which had been run previously for 10 minutes in the cluster corrosion furnace was tested again in an attempt to bring the total test time to 24 minutes. Arcing in the furnace caused a premature shutdown after an accumulated total time at full temperature of 13 minutes. Inspection of the test piece after the test revealed the tie rod had broken in

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several places. The total equivalent time including startup and shutdown ramps was computed as 19 minutes at 4150°R. The block has been sectioned and except for several chips on the end faces and some surface cracks, no apparent damage was observed visually. Photomicrographs were taken of the counterbore area and of the bore cross section. None of the counterbore cracking typically found in other NRX-A3 blocks was observed and only minor subcoating corrosion of the bores was in evidence.

A special NRX-A4 block was run for twenty minutes with temperatures reaching 4700°R to 5000°R. This test was run using NRX-A5 thermocouples. There was no strain gage used and a molybdenum sheet was used over the diffuser. The test was made at 2.4 megawatts for the full 20 minutes. Both thermocouples became inoperative at 41 millivolts (4800°R). The molybdenum sheet lining the diffuser had curled and blocked the viewport used to read the temperatures. Post test inspection showed pressure welding of the block to the element. There was a high degree of corrosion in the crack. There was also a great deal of undercut where the coating stops. The block will be sectioned.

Aluminum Radiation Shield Tests

A series of aluminum radiation shield tests were conducted in conjunction with Ground Support. The test fixture consisted of a simulated aluminum radiation shield which represented the shield to be placed about a segment of the periphery of the NRX-A4 reactor. The tests were designed to determine the ability of the shield to resist failure under hydrogen flame impingement. Four tests were conducted in which temperatures from nine thermocouples were recorded. The simulated shield was cooled with water ranging from 30 to 60 gpm. The first test was conducted with a stainless steel sheet interposed between the flame jet and the aluminum shield. The stainless steel sheet successfully deflected the flame for six minutes before deforming. The stainless steel sheet would probably

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have resisted failure for a greater period of time, or not failed at all, had it been held more securely. The second test was similar to the first with the exception of the stainless steel sheet. No failures were observed.

A third flow test was conducted at a reduced cooling water flow rate and with no stainless steel sheet acting as a deflector. No failures were observed. The fourth test repeated the third with the aluminum shield moved to within 12 inches of the nozzle jet. No failures were observed on this test.

An additional test was conducted on the simulated radiation shield coated with G. E. Silicon Rubber Coating RTV 757. The intent of the coating was to protect the shield against hydrogen flame impingement through the heat resistant and ablative characteristics of the coating material.

Test conditions were the same as those previously conducted. The shield was situated approximately 18 inches from a hydrogen jet nozzle of 0.05 inch diameter. The shield was cooled with water at a flow rate of approximately 60 gpm.

The coating failed almost immediately on start-up. It was observed to peel off in large sections, radially outward from the center of the jet. The sections were brittle and crumbled easily after cooling. Steady state operation was not achieved because of the rapid failure of the coating. There are no future tests anticipated.

NRX-A5 TESTS

EML-61 Tie Rod Evaluation Tests

Static and fatigue tests were performed on hollow instrumented tie rods selected from the shipment of NRX-A5 reactor hardware. Tension tests were conducted on four of the tie rods. The average property values were 225,000 psi ultimate and 194,000 yield, which agreed with results from previous tests on hollow tie rods. However, the percent elongation was 8.9; an increase of twice the previous value.

Fatigue tests at a load range of 800 ± 200 lb on six rods resulted in life-time values greater than 100,000 cycles. Two failures occurred in the shank portion of the rod while the remaining four occurred in the short nozzle end thread. Figure 1 shows the six rods after testing.

Two additional rods are to be tested at cryogenic temperature simulating the extreme offset condition that could occur during reactor operation. At the conclusion of these tests, an evaluation will be made to determine the qualification of the tie rods for NRX-A5.

EML-69 Support Block Mechanical and Thermal Testing

Tests were run in the ten inch furnace to develop data on the corrosion effects of pyrofoil washers in hydrogen at reactor operating temperatures. In these tests, five scfm of hydrogen gas was passed through the inside diameter of a compressed stack of ten pyrofoils. The gas pressure was five psi and average gas temperature was 3200°F.

Three types of pyrofoil were used: high purity outgassed, high purity not outgassed, and low purity not outgassed. A fourth comparison was made by

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FIGURE 1

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inserting a pyrosleeve through the inside diameter of the foils and repeating the test. In this manner the foils were exposed to a hydrogen atmosphere under similar test conditions but not exposed to gas impingement.

Results showed an 18-20 percent loss by weight in one hour and no apparent difference between the three grades of pyrofoil. The loss of area varied closely to the loss of weight which indicated no interstitial corrosion between the pyrofoil layers. The foils which were not exposed to gas impingement lost only 0.09 percent of their weight while the pyrosleeve lost 11.1 percent. These results were verified by tests performed in the single element testing rig at WANHES. Therefore, the pyrofoil should have a lifetime equal to any of the support block components when not subjected directly to an impinging stream of hot hydrogen gas.

An A5 uncoated support block with a 60 mil radius was instrumented with strain gages in the fillet radius area and loaded to 1000 lb in the Wiedemann machine. There was a 20 percent reduction in strain, axially, when compared to a similar A3 support block with a 20 mil fillet radius.

Tests on the same instrumented block were conducted in the 10 inch furnace at room temperature to verify the results obtained in the Wiedemann machine. The strain gages indicated results almost identical for the same loading in the different test equipment. Deliberate misalignment of the specimen was introduced to determine the effects on the readings. This produced distinguishable results which indicated that there was no misalignment in the previous tests.

Cracks were produced in NRX-A5 type blocks in a manner similar to the NRX-A4 block explained previously for tests performed in other areas.

During the next period, tests will be performed on coated A5 reactor-grade support blocks and washers. Crack initiation values will be determined for the hardware combination to be used in A5 reactor.

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EML-75 Friction Tests of Reactor Components

Filler strip and fuel element specimens coated in the same manner as the components which will be installed in the NRX-A5 reactor were tested to determine the friction and coating wear that would occur during ten reactor tests run of ten minute duration. The tests were performed in hydrogen at temperature and contact pressure conditions expected along the axis of the reactor. The test conditions and friction coefficients measured are tabulated below. No significant damage of the coated surfaces was found at the conclusion of the tests, but some corrosion of the pyrotile surfaces which had been tested at 4170°R and 4300°R was observed. Additional tests at 4300°R are now being made in which weight loss will be measured in order to assess the significance of the pyrotile corrosion.

Interface	Contact Pressure (psi)	Test Temperature (°R)	Static Coefficient Friction
Fueled Element - Pyrotile	10	1950	0.10
Fueled Element - Pyrotile	20	3350	0.20
Fueled Element - Pyrotile	20	4170	0.60
Partial Element - Pyrotile	10	1950	0.10
Partial Element - Pyrotile	20	3350	0.23
Partial Element - Pyrotile	20	4170	0.77
Partial Element - Pyrotile	15	4300	0.93
Filler Strip - Pyrotile	125	4170	0.6
Filler Strip - Pyrotile	100	4300	0.6

Data obtained from these tests will be evaluated by Reactor Design to determine the total friction forces that will occur axially along the core periphery during reactor operation.

EML-76 Reactor Hardware Static and Dynamic Tests

a. Instrumentation and Emergency Purge Port Tests

Qualification tests of the NRX-A5 instrumentation seal block and emergency purge port assemblies as shown in Figure 2 have been completed during this period. Vibration, thermal cycle fatigue and pressure shock load tests were performed. The tests were required to prove the ability of these designs to contain gas pressure without leakage during reactor operation. The test results indicated no structural failures or inability of the assemblies to function after being subjected to the test requirements.

An alternate design of the instrumentation seal block will be proof tested during the next period. It was explained at the request of G. Kalvin that instrumentation revisions at the test site may require the use of the alternate design over the present existing design.

b. Control Drum Scram Spring Tests

An additional maximum displacement cycling test of the NRX-A5 control drum scram spring attachment hardware was performed at ambient conditions with a redesigned positioning fitting for the stationary end of the spring. This fitting incorporated a key for locking the fitting in place (see Figure 3). The fitting remained securely locked in position and prevented any translation of the spring relative to the control drum bearing shaft throughout the test.

EML-86 Lateral Support System Tests

Static tests were conducted to determine friction characteristics, wear and structural integrity of the NRX-A5 lateral support system components.

These tests were required to compare the friction bundling characteristics of the new A5 plunger seal configuration with those of previous NRX-A6 reactor design. Sketches of each design are shown in Figure 4 for comparison.

FIGURE 2
TEST SPECIMENS
EML-76

FIGURE 3
LOCKING DEVICE - CONTROL DRUM SCRAM SPRINGS
EML-76

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FIGURE 4
COMPARISON OF A5 & A2 PLUNGER DESIGNS
EML-86

FIGURE 5
END CAP OF TEST FIXTURE USED TO APPLY
MULTIPLE AXIAL LOADS TO IRREGULAR CLUSTER
EML-94

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The test was performed on a partial length core which included a ten inch high inner reflector, three rows of seal segments and associated springs, plungers, and hardware. Each plunger was selectively fitted into the reflector holes per NRX-A5 assembly requirements.

The test results indicated that the friction characteristics are similar to previous reactor designs and no excessive wear or structural failures occurred.

The friction values were obtained by displacing the core from the longitudinal centerline and recording the displacement vs force through a total of twelve cycles.

A summary of the friction characteristics derived from the test data and the corresponding NRX-A2 values are given in Table III.

TABLE III

Friction Characteristics Extrapolated from Test Results

	<u>Cycle 3</u> <u>A5 Design</u>	<u>Cycle 12</u> <u>A5 Design</u>	<u>Average</u> <u>A2 Design</u>
Spring Rate (K)	43,800 lb/in	43,800 lb/in	44,160 lb/in
Static Friction Force (P)	6,450 lb/in	7,080 lb/in	7,260 lb/in
Static Dead Zone (From Curve)	.150 in	.162 in	.162 in
Static Dead Zone ($\frac{P}{K}$)	.147 in	.162 in	.164 in
Natural Frequency (F_n)	11.7 cps	11.7 cps	11.8 cps
Static Deflection (ΔS)	.071 in	.071 in	.070 in

Values are shown for the third and twelfth displacement cycles. The static friction force value (P) increased to 7080 lb which differs by 2 to 3 percent of the NRX-A2 data.

EML-88 Insulated Control Drum Bow Tests

Additional thermal bow tests of an NRX-A5 control drum were carried out to confirm the variation of maximum drum bow with drum initial temperature. Initial drum temperatures of 660 and 720°R were investigated with a simulated flow ramp of 1.0 lb/sec². The data obtained indicated good agreement with the original measurements. The original and retest maximum bow measurements are compared in Table IV.

TABLE IV

<u>Initial Drum Temperature (°R)</u>	<u>Original Bow Measurement (in.)</u>	<u>Retest Bow Measurement (in.)</u>
660	0.015	.016
720	0.009	.011

The report, "Insulated Control Drum Bow Tests," is in the process of being released.

EML-94 Buffer Periphery Testing

Tests to evaluate the capability of the buffer periphery design were continued during the period.

a. Key Integrity Tests

Static tests, performed on the two types of keys used in the periphery of the A5 reactor, indicate the strength to be greater than the maximum load of 70 lb expected in NRX-A5 power tests. Typical failure of keys occurred at loads between 238 and 407 lbs.

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b. Support Block Cocking Tests

A series of cocking tests on the five irregular support block configurations were completed. Loads representing the axial pressure drop across the filler strips were applied to the irregular clusters at the partial element position. The following results were obtained using uncoated elements tested at ambient conditions.

<u>Irregular Cluster</u>	<u>Partial Element Load for a 150 psi Pressure Drop Across Filler Strips (lb)</u>	<u>Minimum Bundling for no Motion (psi)</u>	<u>Deflection at Point of Loading</u>
J3	300	10.2	72 mils at 4.5 psi 38 mils at 8.1 psi
J4	238	3.5	*
J5	126	11.6	39 mils at 2.7 psi 31.5 mils at 7.2 psi
J6	136	3.9	*
J8	122	2.2	*

*Low bundling pressures resulted in lateral motions of adjacent clusters, therefore, recorded deflections are considered unrealistic.

Additional tests, using a multiple loading condition, shown in Figure 5, were conducted on the J3 and J5 configurations. Elements, which would be located adjacent to the filler strips, were loaded simultaneously. The small angle of cocking above one psi bundling was attributed to an undersized element. The maximum displacement was approximately two mils.

c. Radial Expansion Test

A test is required to determine the radial gap effects when expansion occurs in the NRX-A5 composite core periphery. In the A5 reactor two sectors

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of the existing core periphery design are to be replaced by two sectors of the Buffer Periphery design.

A test rig and partial length core is being assembled to simulate reactor conditions.

HHT-1 Quality Control Fuel Element and Block

During the period December 3, 1965 through January 26, 1966 a total of 181 tests were made; 53 were Q. C. tests of Astrofuel A5 elements, 49 were Q. C. tests of Oak Ridge elements, and 79 were special tests.

HHT-2 Single Element Process Development and Evaluation Tests

Five corrosion tests were run on single hole (Code 03) elements. Four of the samples tested were partial elements. They were tested to determine if debris in the flow channel before coating degraded the bores. The channel of two of these was brushed clean to determine if this treatment would cause any corrosion problems. Although three of the elements suffered external corrosion at 51 inches, none of them lost over 0.6 grams or seemed seriously damaged by a 10+10 minute test. Two additional candidate batches may be tested in the future.

HHT-4 Single Cluster Development Test

A three cycle endurance test of an NRX-A5 configuration support block was successfully completed in January. The support block was a coated NRX-A4 block modified to the 60 mil counterbore radius representing the NRX-A5 configuration and with a 10 mil pyrographite washer under the support washer. The support washer was not recoated after machining. The first cycle included a power increase ramp of about 20°R per second, 20 minutes at full power, and a power decrease ramp of about 20°R per second. The total steady-state time at full power for the three cycles was 33 minutes. Additional test time may be logged on this configuration.

In general, the foil appeared to have resisted corrosion except for a small amount on the periphery. The coated pyrographite support washer underwent substantial corrosion on the uncoated periphery.

HHT-7 Filler Strip Corrosion Test

The next build (Build 4 Test 2) containing the NRX-A5 simulating transition from the hot to cold buffer configuration is scheduled for the next peripheral cluster test. Although this test competes with the fuel element cluster test, it is tentatively scheduled for March.

FFL-18 Single Seal NRX-A5 Tests

A build containing an A5 seal segment with an extra A5 scarf joint with approximately .000 inch ramp clearance and a square edge has been run using a mixture of water and air. A second build containing an extra scarf joint of the A6 length with approximately .000 inch ramp clearance and a sharp edge has also been run. These tests were flow visualization tests to determine the major flow leakage path. It was observed that the primary leak-path was through the scarf joints. It has been determined that a scarf joint with a sharp edge will reduce the leakage by approximately 50%.

FFL-20 Inner-Outer Reflector Impedance Ring

Assembly, instrumentation and installation of the model was completed. Tests will be performed using air to measure loss coefficient versus Reynold's number across impedance ring and determine pressure drop versus flow through the annulus.

FFL-21 Tie Rod Hardware Flow Tests

Pressure measurements in the counterbore and channel of the support block cold flow model were completed.

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FFL-23 Nozzle Interface Seal Performance Test

Fabrication of the model and leak check fixtures required to flow test nozzle interface seals for the NRX-A5 reactor was completed. Testing of the seals will be conducted this month.

FFL-27 NRX-A5 Instrumentation Port Qualification Tests

Using an internal pressure of 800 psig gaseous helium, fifteen thermal cycles were completed on each of three seal block assemblies. Each fixture was checked frequently for leakage at the ambient temperature by observing a pressure change in a trapped volume with hydrogen gas at 800 psig. In addition, Leak-Tec solution and the hydrogen sniffer were used to check for local leakage points. No leaks were found.

One fixture from the thermal cycling was compressed axially in a tensile test machine with a total deflection of 50 mils. The welds seemed unaffected by the loading. The leakage rate from the brazed joint by the trapped volume change was determined to be 5×10^{-2} scc/sec for an 800 psig hydrogen gas differential pressure across the seals.

Two seal block assemblies were struck with a two pound weight from four and then eight feet vertical heights. A leak rate measurement determined that no leakage could be detected under gaseous hydrogen pressures of 800 psig after these tests. One assembly was then struck with a 10 and a 20 pound weight from a four foot and eight foot vertical drop on the end of the arm of a pendulum. The seal tests have been completed satisfactorily on the primary, brazed seal, design.

The back-up configuration that includes an Aeroquip-Marman conoseal and flange has been tested and found also to be leak free at 800 psi with hydrogen gas at ambient temperature. The two assemblies supplied were leak checked at liquid nitrogen temperature and then rechecked at ambient temperature and found to be leak free.

NRX-A6 TESTS

EML-60 Core Effective Gap Tests

a. Pinhole Test

A test to investigate the effects of pinholes on core interelement flow and pressure distribution was performed utilizing the core effective gap test setup. Four elements containing pinholes approximately .070 inch in diameter were placed within the core. Each of these elements was sealed so that the bore pressure at the pinhole was either greater or less than the local interelement pressure. Interelement pressure probes were located immediately adjacent to and approximately 1.5 inch from each pinhole.

Flow tests were then performed duplicating previous core gap test conditions. An input pressure of 100 psig and a differential pressure of 35 psi was applied across the core using helium gas. A uniform lateral bundling pressure was varied in steps from three to ten psi. The measured interelement pressure profiles immediately adjacent to and at 1.5 inch from each pinhole are shown in Figure 6. Measurements of interelement pressure previously obtained without pinholes are given for comparison purposes.

Only a small effect on interelement profile was measured when the bore pressure at a pinhole was below that of the interelement pressure. A significant effect was measured at one pinhole which had a bore pressure in excess of the interelement pressure (see Figure 6a).

A second test will be performed in which the flow into and out of selected pinholes placed within the core will be measured. Each element containing a pinhole will be alternately sealed at the inlet and outlet ends. The pinhole flow rate and the interelement pressure profiles for each condition will be measured.

FIGURE 6
 INTERELEMENT PRESSURE PROFILES
 (10 PSI BUNDLING PRESSURE)
 EML-60

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In response to Mr. Calvin's question about why we selected 10 psi for this particular test, it was pointed out that our previous test results show that bundling pressures above 10 psi have little effect on interstitial gaps. We will re-examine this point and if necessary, make additional runs with 15 psi bundling pressure.

b. Pinhole Impedance

The unrestricted impedance to flow of each pinhole was measured using a fuel element porosity test fixture. The element is placed within a chamber and the pinhole opening temporarily plugged. The system is then pressurized to 100 psig using helium gas. Flow occurs either into or out of the pinhole depending upon which end of the element is placed within the chamber. Gas flow rate is determined from the chamber pressure change using the relationship:

$$\frac{dW}{dT} = \frac{V}{RT} \frac{dp}{dt}$$

Chamber Volume	V	- .085 ft ³
Gas Constant	R _{He}	- 386
Temperature		- 530°R

The flow rate through the four pinholes was nearly equal. At 100 psig chamber pressure the flow is approximately 1.3×10^{-3} lb/sec.

EML-69 Support Block Mechanical and Thermal Tests

Development-grade hardware with a variety of washer configurations was tested to determine the best possible combination for use in NRX-A6. The washers tested consisted of foils, ATJ (150 mil thick) and pyrowashers.

Tests run with ATJ washer and cup were successful up to loads of 1500 lb in the thermal cycle. This was in agreement with previous results obtained with uncoated specimens. Tests conducted on a combination of foil and ATJ washers, and pyrographite washers resulted in lower cracking loads than the ATJ washer and cup.

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Additional tests were run on coated A6 corrosion cups and coated washers of 150 mils thickness. This combination was tested at various loadings to establish a cracking threshold in the cup with the load held through warmup, temperature, and cooldown. Hydrogen gas at 4300°R was passed through the test specimens while at temperature.

Seven tests were run from 1000 to 1700 lb. In all cases the washers welded solidly to the cups and the assembly had to be sectioned and polished to interpret the results. It was established that crack initiation occurs between 1500 and 1600 lb. No cracks penetrated to the outside surface of the cups. The ATJ washers deformed slightly under loading and expanded a small amount diametrically which tended to reduce the clearance between the washer and cup wall. Cracks occurring on the inside surface diameter of the washer did not penetrate into the graphite. Figure 7 shows sectioned cup and washer.

The ATJ washers cracked badly between 1800 and 1900 lb when tested with the corrosion cup at room temperature. A very fine crack was discernible in the inside fillet radius of the corrosion cups but sectioning is necessary to determine whether the crack penetrated the graphite. Therefore, it is apparent that the cup cannot be loaded to failure through an ATJ washer. Results also indicated that coating the components does not make an appreciable difference in strength from uncoated parts tested previously.

A test was run to weld a corrosion cup to skirtless support block for additional corrosion testing. The cup was welded to the block at 4750°R for one hour under a load of 800 lbs. This assembly was then forwarded to the Fluid Flow Laboratory for corrosion testing in their single element furnace.

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FIGURE 7

SECTION VIEWS OF CUP AND WASHER AFTER TESTING
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EML-70 Blockless Support Systems

a. Strength of Brazed Tie Rod Collar

An evaluation was performed to determine the integrity of a brazed tie rod collar assembly proposed for support redundancy in the event of failure in the primary support system in a cluster assembly. The test assembly consisted of a split inconel collar brazed to a section of the tie rod. In the event of failure in the primary support of the cluster during reactor operation, the keyed elements will be supported by the brazed collar on the tie rod. The specimen submitted for evaluation was observed to have a poor band in that voids between the collar and the tie rod were visible. However, the brazed split collar withstood loads up to 1650 lb when failure occurred in the tie rod.

b. Strength of Brazed Keys on Fuel Elements

A total of eight specimens with keys brazed on fuel elements were tested for load carrying capabilities. The specimen had been modified by machining approximately 7/16 inch from each key down to the braze.

The loads required to produce cracking varied from 88 to 220 lb with an average of 170 lb for the eight specimens. All failures occurred through the braze and into the element; in no case did the crack initiation begin in the key.

c. Strain Distribution Along Length of Keyed Element

A series of tests were conducted to measure the strain distribution along the length of keyed elements when subjected to axial and lateral bundling loads. Three elements keyed at the dome end and instrumented with strain gages were placed in a central cluster and tested in the seven cluster test assembly rig. Axial loads were applied at the dome end only through the three keyed elements by hydraulic cylinders.

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At a lateral pressure of zero psi all the load was transmitted through the keys and the central element and to the central tie rod. The six peripheral clusters were supported by standard support blocks and tie rods. As the lateral pressure was increased the tensile strain in the critically stressed region of the key and element was reduced or reversed (placed in compression) for a given axial load. The results of strain in the critically stressed region versus bundling pressure are tabulated in Table V.

TABLE V

Bundling Pressure (psi)	Average Strain (10^{-6} in/in)		
	Keyed Element "A"	Keyed Element "B"	Keyed Element "C"
0	596	538	747
3	383	570	195
6	197	424	18
12	-123	274	-146
21	- 65	75	-211
21	- 60	59	-157
21	- 67	75	-151

EML-86 Lateral Support System Tests

Detail drawings of the test fixture components were completed this period. Procurement of the test hardware is continuing with delivery scheduled for next period.

Detail test plans will be developed in the next period for the static, dynamic and seal leakage tests. These tests will evaluate the NRX-A6 lateral support system configuration.

EML-92 Thermal Contact Resistance Tests

Tests to determine the thermal conductance coefficients for materials to be used in the NRX-A6 lateral support system were completed this period. A summary of the tests and preliminary results are given in Table VI. The values for thermal conductance were taken from preliminary plots of test data and will be evaluated after detail analysis of the test data.

HHT-2 Single Element Process Development and Evaluation Tests

Ten 60 minute element life tests were made at WANHES. Two of the ten survived the full 60 minutes. The other eight failed from either the hot end chuck breaking or the element breaking or both. Future tests are planned in this area both at WANHES and Large.

FFL-18 Single Seal NRX-A5 Tests

Fabrication has been completed on two seal segments containing an extra scarf joint of the A6 length and .000 and .002 inch ramp clearance. Hydrogen leakage tests will be run on these in the near future.

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TABLE VI

Summary of Tests and Results

Test Conditions		Preliminary Results			
ATM	Interface Pressure	Interface Temp., °F		$\Delta T + ^\circ F$ Across Grafoil	$h \frac{BTU-}{hr-ft^2-^\circ F}$
		Gr	Be		
VAC	50	495	210	285	88
VAC	100	523	215	308	87
VAC	300	500	205	295	93
He	50	375	185	190	130
He	100	380	190	190	118
He	300	385	197	188	116
He	50	83	64.2	18.8	126
He	100	83.7	64.0	19.2	126
He	300	83.5	64.0	19.5	126
He	50	- 65	-260	195	152
He	100	- 70	-235	165	198
He	300	- 77	-235	175	202

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GENERAL DEVELOPMENT TESTS

EML-55 Resonant Survey of ETS

Preliminary work has been started on the Resonant Survey Test to be performed on the XECF Reactor at NRDS. The test plan has been incorporated in the "Preliminary XECF Test Plan." In response to a question by Mr. Kalvin, it was pointed out that both AGC and WANL believe that the information obtained from this test to be important to the overall test program.

EML-60 Core Effective Gap Test

The permeability of fuel elements to gas flow is an important property affecting corrosion and core interelement pressure. Basic information is required on the permeability of graphite elements and the effect on permeability of various coating and impregnation processes.

A test rig has been fabricated to measure the porosity of fuel elements at gas pressures up to 800 psig. The test procedure consists of establishing a differential pressure between the bore and external surfaces of an element. The pressure rise within the bore provides a measure of the gas flow rate through the element into the bore using the relationship:

$$\frac{dW}{dT} = \frac{V}{RT} \frac{dp}{dt}$$

V - Bore Volume
R - Gas Constant
T - Temperature

EML-61 Tie Rod Evaluation Tests

Two 3/8 inch diameter fiber graphite tie rods were tested in tension for a first evaluation of the new load bearing end. Both failed at a relative low load of 1200 lb. One rod failed at the transition zone due to excessive twist in the fibers; the other rod pulled through the holder due to extrusion of the end plug.

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Nominal stress was approximately 12,000 psi as compared to a maximum of 32,000 psi obtained on the 1/2 inch diameter development rods. Specimens taken from rods have indicated a fatigue strength under completely reversible bending above 30,000 psi.

EML-82 Outer Reflector Sector Tests

a. Leakage Test

Gas leakage through a crack in a beryllium specimen with thin webs was measured in order that estimates might be made of leakage that would occur through thermal stress cracks in the thin webs of a reflector sector. The crack approximately 10^{-4} inch wide was produced by subjecting the specimen to a thermal shock with cryogenic gas flow. The leakage was measured by determining the change in the pressure of a helium gas supply over a period of 21 hours. The gas pressure during the test was about 1800 psi. This pressure was selected in order to obtain about the same leakage that would occur with hydrogen at reactor operating conditions.

The leakage measured was about 4×10^{-3} lb/hour/inch of crack length. A 100 magnification of the crack cross-section appears in Figure 8.

b. Strain Cycling Test

A beryllium test specimen which had been previously strain cycled in tension and compression was subjected to additional strain testing in order to further study the strain cycling capabilities of reflector sector material. The additional testing consisted of ten cycles at 140°R with maximum tension and compression strains of about 1500μ in/in. This was followed by seven cycles at 140°R with maximum tension and compression strains of 1700μ in/in. Failure of the specimen occurred at one of the threaded ends at the end of the last 1700μ in/in strain cycle.

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FIGURE 8

CROSS SECTION OF CRACK AT 100 MAGNIFICATION
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Additional strain cycling tests will be performed with other specimens machined from material batches which bracket the range of material quality obtained in sector pressings to date.

HHT-2 Single Element Process Development and Evaluation Tests

A single element test with plugged peripheral holes was made. The test was inconclusive because of insufficient radiant thermal energy transfer. Another test will be made using resistance heating in order to obtain the desired temperatures.

Six hydrogen corrosion tests were run in the A2 furnace to study pinholing behavior in A4 fuel elements. The elements were tested at Q.C. qualification standards of reactor candidate conditions with the exception that the helium atmosphere outside the element was held at a pressure of 20 pounds lower than the hydrogen pressure inside the element at the midband area; a condition which will drive hydrogen through any cracks in the channel coating, producing pinholes in the element surface. This condition was attainable by providing a positive seal of the hydrogen inlet line to the cold end of the element (using the direct gas inlet chuck). This chuck permits the pressure of the element external environment (the inert helium pressure) to be reduced to 100 pounds below the hydrogen inlet pressure, without risk of leaking hydrogen into the inert atmosphere.

Three conditions were tested: (1) setting 660 psig hydrogen inlet and 630 psig helium atmosphere provided a 20 pound pressure difference at the midband and produces pinholing at 11 inches from the cold end; (2) setting 660 psig hydrogen inlet and 610 psig helium atmosphere shifts the 20 pound pressure difference to the 25 inch station; and, (3) setting 660 psig hydrogen inlet and 560 psig helium atmosphere which shifts the 20 pound pressure difference to the 44 inch station. Pinholing was noted from 20 thru 36 inches and again in the 48 thru 52 inch range.

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The extent of pinholing is a function of time and the coating quality. Only one test run for 10 minutes or less showed any signs of pinholes. All of the elements tested for 10+10 minute cycles showed pinholes to varying degrees. Certain batches pinholed badly regardless of pressure conditions and others showed relatively little sign of pinholing despite more severe conditions. Preliminary results seem to indicate that this type of test may be useful to predict the relative pinholing behavior of future reactor candidates and to test the quality of "crack" free coatings.

A tungsten-26% rhenium thermocouple was placed through the wall of the A2 diffuser, approximately 12 inches from the hot end of the fuel element, in order to obtain preliminary measurements of corrosion test gas temperature. A view port placed at right angles to the thermocouple allowed measurements of the surface temperature of the tip (which protruded 1/2 inch into the gas stream) with an optical pyrometer. Recordings of the thermocouple signal seemed to follow closely. Changes made in the element power level indicated that the measurements were of the gas temperature and not surrounding material. The gas temperature level indicated by the thermocouple was 4460°R on each of the five tests run. This condition was obtained when the element surface temperature at 48.5 inches measured 4600°R . The internal material temperature at the same location has been measured at 4950°R by observing a drilled hole in the element. The optical measurement of the thermocouple surface temperature came out to 4476°R , agreeing well with the emf indication.

HHT-6 Interstitial Corrosion Tests

Three long gap tests were run. The test was set up with a center hex with a cylindrical rod through the hole in the center of it. The gap was maintained by using molybdenum pins. One test was run with a 5 mil gap for 60 minutes and two tests with a 10 mil gap for 50 minutes each. Corrosion, plating out and bonding were noted.

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Two coating evaluation tests were run on specimens having both ZrC and NbC coated faces. The first test ran for 30 minutes at average material temperatures of 3518^oR. The weight loss of the ZrC coated section of the specimen was .541 gms and the NbC section the weight loss was .272 gms. Both coatings for the first 1/4 inch of the flow slot show areas of break-through and discoloration. The ZrC showing more damage than the NbC. From the 1/4 inch station to the exit of the flow slot both coatings were intact and appeared to be in good condition.

The second test ran for approximately 12 minutes with test conditions similar to the first test. The weight loss of the ZrC section of the specimen was .745 gms and the NbC section was .101 gms. Examination of the specimen showed the NbC coating to be intact while no trace of the ZrC coating could be found.

HHT-7

Filler Strip Corrosion Test

A hot buffer filler strip corrosion test was conducted with a model core consisting of a 180^o sector of ZrC coated filler strips and a 180^o sector of uncoated filler strips. The test ran for eight minutes at operating temperature levels. Preliminary observation showed relatively severe corrosion in both the coated and uncoated filler strips. There was very little corrosion noted on the core surface under the sector of the coated filler strips. There was, however, corrosion noted under the sector of uncoated filler strips in the area where the highest temperature level occurred.

A peripheral design study for the filler strip cluster test using gas injection is presently in progress. The details of the study can only be fixed after a configuration is finalized but the system problems associated with such gas injection peripheral are being determined.

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FACILITIES

The following areas were covered in the discussion of facilities: High pressure furnace, lateral support system and vacuum equipment. The furnace will be used for tests that require mechanical load and strain measurements under combined pressure and temperature conditions. Equipment for evaluation of the lateral support system has been defined and procurement initiated. Specifications have been prepared for a vacuum chamber to be used in environmental testing. This information will be used in the procurement of the hardware.

The WANHES liquid hydrogen pump vaporizer has been checked out and a complete hydrogen system is virtually complete. Approximately one week of work is required to complete this system.

The Large Site vaporizer is installed but not qualified. Work is continuing in preparation of qualification tests.

The new A2 furnace has been delivered. Preparations are being made to complete the installation.

Bids have been received on the new dewar. Because of the strict specifications the bids are much higher than expected. An off-the-shelf dewar could be purchased and installed for approximately \$50,000.00. One built to our specifications is about twice this price.

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