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February 1967

Westinghouse Astronuclear Laboratory

NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW MEETING
HELD WITH SNPO AT WANL ON JANUARY 26, 1967
(Title Unclassified)

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Mr. J. L. Boring
Federal Industrial Manager
 
(1970, Washington, D.C., February 1970)

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

SPECIAL REVIEW FINAL DETERMINATION	Reviewers	Class.	Date
	KAW	U	5-13-82
Class: <u>U</u>			

Classification cancelled for change to
by authority of DOE
by 1071.C. TUC, date SEP 10 1973

E. A. DeZubay, Manager
Fluid Flow Laboratory

W. J. Rowan, Manager
Engineering Mechanics Laboratory

INFORMATION CATEGORY

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Attendees:

Bermingham, A. J.	AGC	Murphy, H.	SNPO-C
DeZubay, E. A.	WANL	Olinger, J. S.	WANL
Fix, H. J.	WANL	Rowan, W. J.	WANL
Gagne, R.	SNPO-C	Salvador, L. A.	WANL
Hoffman, H.	SNPO-C	Schreiber, J. J.	WANL
Kalvin, G.	SNPO-C	Tauch, F. G.	WANL
Kanter, I. E.	WANL	Thompson, D. C.	WANL
Kelly, V. G.	WANL	Watjen, E. A.	WANL

The Monthly Development Test Program Review Meeting was held at WANL on January 26, 1967.

Lists of the tests performed during the month of January and those planned during the next period were distributed to those in attendance. These test programs are shown in Tables I and II.

The individual tests were then discussed by each department in the order shown in the Tables.

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TABLE I
THERMO-FLOW LABORATORY TEST SCHEDULE

PERFORMED THIS PERIOD		PLANNED NEXT PERIOD
Tests for NRX-A6		
TFL-1. a	Cluster Test - One Cycle Each on Developmental Carbide Composite Protection Cup and Tungsten Protection Cup.	Complete Tests on Developmental Carbide and Tungsten Cups. Exit Gas Thermocouple and Production (Irregular) Cup.
TFL-1. b	Single Element Corrosion Tests - Completed Four Tests for Facility Check-Out.	Continue Testing.
TFL-2. a	Filler Strip Tests - Completed Tests of Hot Buffer Periphery With Double Pyrofoil Wrapper.	Design and Procure New Model.
TFL-6. a	360° Reactor Shield - Continued Ingestion Tests.	Continue Testing.
Tests for NRX-A7		
TFL-2. c	Plunger Pin Capsule Seal Tests - No Activity	Conduct Tests.
Tests for NR-1		
TFL-2. d	Plunger Pin Capsule Flow Impedance Test - Completed Testing.	No Activity.
General Development		
TFL-5. b	Interstitial Corrosion-Filler Strip Tests.	Continue Testing.
TFL-5. c	Permeability - Conducted Tests on Heated Fuel Element.	Continue Testing.
Facilities		
Completed Installation of Guard Heater Power Supply. Work Continues on Data Trailer.		

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TABLE II
ENGINEERING MECHANICS TESTING

PERFORMED THIS PERIOD (Jan.)

PLANNED NEXT PERIOD (Feb.)

Tests for NRX-A6

EML-C.1 Carbide Composition Cup Tests
EML-D.5 Lateral Support System Dynamic Tests

EML-C.1 Tungsten Irregular Cup Tests
EML-D.5 Wrapper Evaluation in Lateral Support System Dynamic Environment
EML-E.2 Continue Friction Tests
EML-E.3 Aft End Flow Impedance Tests with Pyrofoil Seal Sleeves

Tests for NR-1

EML-A.4 Fabrication of Titanium Band Specimens for Material Property Tests
EML-C.4 Poison Wire Test Structure

EML-A.4 Initiate Material Property Tests
EML-C.4 Fabrication of Test Structure

General Development

EML-B.1 Permeability of Fuel Elements at Temperature
EML-E.1 Core Wrapper Strain Tests
Core Wrapper Temperature Tests
Filler Strip Strength and Thermal Gradient Tests
EML-H.2 Specimen Evaluation for Acoustic Tests

EML-A.1 Insulating Cylinder Fastener Tests
EML-B.1 Permeability Tests of Molybdenum Coated Elements
EML-E.1 Core Periphery Pyrofoil Wrapper Tests
Additional Filler Strip Strength Tests

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NRX-A6 TESTS

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TFL-1.a Single Cluster Development Tests

There were two cluster tests conducted during the period of December 21, 1966 through January 25, 1967. The purpose of the tests was to evaluate a developmental composite (carbide) and a tungsten protection cup. The first test was conducted using the composite cup and operated for a period of 23 minutes at a temperature of 4300°R. All test parameters were attained. There was no damage to the block or protection cup although some coating was lost from the insulating cup. Welding occurred between the support washer, block, and protection cup. A second cycle using the same block and protection cup was conducted and operated for a period of 24 minutes at a temperature of 4300°R. Once again all test parameters were attained. Although the test was terminated because of a temperature excursion on the tie rod exit gas, the block and composite protection cup were undamaged.

The second test was conducted using a tungsten protection cup. The test operated for a period of 30 minutes at 4300°R. All test parameters were attained and the test was terminated by a normal shutdown. Post test inspection showed that the block was undamaged and the insulating cup had suffered only a slight loss of coating. It is planned to perform another cycle on each cup in order to attain a total test time of 60 minutes.

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

A general maintenance program for equipment in the single element cell was completed.

A computer printout for Phase I-1C of the Fuel Assessment Program was issued. A combination data sheet and coding form were put into use for single element tests so that punched cards can be prepared from the original data sheet eliminating copying of data.

Computer programs were completed and are in use for the following purposes:

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- a. Summary Sheet for Weekly TWX.
- b. Data Sheets for Reports.

The new furnace electrode transition connector equipment and short heat exchanger were installed in the single element cell. This installation required the use of a modified graphite hot end retainer and additional molybdenum shields. The new design was evaluated in a series of four single element tests. The heat exchanger exit gas temperature was excessive in the initial two tests without spoilers in the heat exchanger tubes. After the installation of coiled wire molybdenum spoilers, two additional tests were conducted and at flow rates as high as 700 scfm, the heat exchanger exit gas temperature was not excessive. The temperature profile of the element also appears to be within the nominal range at several power levels.

Planned tests for the single element furnace are the Phase II-1B, power and flow series, to be followed by the high void element tests. Other tests planned include the following:

1. Single hole radiant heated.
2. Nine inch passively heat element section.
3. Boron nitride interstitial sleeve.
4. Two minute blowdown.
5. NRX/EST and NRX-A5 simulations.
6. Long hot end chuck.
7. Guard heater.
8. Water injection in heat exchanger.

TFL-2. a Filler Strip Corrosion Tests

A filler strip corrosion test model using normal hydrogen was tested during the period December 21, 1966 through January 25, 1967. The test was conducted in a series of three cycles for a total time of 125 minutes. The total test time at the 30 inch station, where the peak temperature was in excess of 3000°R, was

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estimated to be 90 minutes. The test model included a full complement of full length hot buffer type insulating tile, a 360° wrapper of peripheral impedance liners, and an uncoated inner core. The peripheral impedance liners were made from 0.005 inch thick non-thermalized graphite tape, 3.350 inches wide by 46.875 inches long. The wrapper consisted of two layers of peripheral liners with each layer containing three axial liners. The model also included a spring loaded lateral support system, an NRX-A1 through A4 type seal system and a full-length graphite inner reflector shrouded with a stainless steel jacket. In order to produce a staggered effect similar to the NRX-A6 reactor design, the joints between adjacent liners of the second layer were assembled to terminate at the mid-chord width of the first layer.

The primary hydrogen flow system of the test model was designed to by-pass the mid-core seal system which maintained the pressure level in that region at approximately core inlet pressure. The flow was directed to re-enter the seal system between seal rows 15 and 16 (Figure 1) allowing the flow to pass through the last two seal rows in order to produce the pressure drop across the model. The temperature limitations of the springs in the lateral support system made this maneuver necessary. The reactor design having a minimum leakage type periphery, the by-pass flow system was a compromise to provide both the minimum leakage flow with sufficient external coolant flow for the springs. The test data is presently being compiled and reduced for engineering evaluation prior to release. Work on a new design is progressing in preparation for another test in April 1967.

TFL-6. a 360° Reactor Shield Test

Tests were conducted using a hood attached to the duct that directs the flow toward the reactor centerline (Figure 2). The results of these tests indicate that no adverse effects are produced by the hooded duct. Manifold ring flow is required only for purging of the annulus and not for suppression of the ingestion as produced by a hoodless straight duct.

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TFL-2A-0001 MODEL SCHEMATIC

FIGURE 1
FILLER STRIP CORROSION MODEL

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FIGURE 2

360° REACTOR SHIELD MODEL

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Tests were also conducted to determine the effects of nozzle flow on the annulus flow. The nozzle exhaust had no apparent effect on the flow distribution in the annulus; however, it did draw the gas above the impedance collar upward. It is planned to continue the testing in the future.

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EML-C.1 Carbide Composition Cup Tests

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Five development carbide composition test specimens were available during the last period. Three of these were tested in furnace tests and two at room temperature. The furnace tests consisted of two types: (1) the constant load temperature cycle in which the specimen is loaded, brought up to temperature and cooled down under a constant load and (2) a step load cycle where the load is increased gradually as the specimen is brought to temperature and decreased gradually on cooldown.

Two of the specimens were tested in the constant load thermal cycle test (one at 800 lb and one at 1000 lb). The 800 lb specimen cracked about 3/4 of the way through the web thickness and is shown on the photo-micrograph (Figure 3a). This specimen was made from a LASL billet of 75 percent NbC and 25 percent carbon material. The other specimen shown in Figure 3b cracked after 1000 lb loading in the constant load thermal cycle test. This specimen was machined from a Carborundum billet of the same composition and the crack extended through the coating but did not progress deeply into the substrate. The cup tested with the step loading did not crack at 800 lb, but gave indication of cracking on a repeat test at 1000 lb and was definitely cracked at 1200 lb. The room temperature specimens were both loaded to failure. One of these failed at 2300 lb and the other at 2575 lb. In both cases the edge of the cup contacted the support block surface just before failure. Both of these specimens started with an initial eight to ten mil clearance between the cup and the block. These results led to further tests to determine the permanent deformation of the ATJ washers after 60 min. at 700 lb in the furnace at 4300°R. These tests are currently in progress and will be reported next time. Future work will also consist of additional tests of tungsten irregular cups and composition cups as they become available.

EML-D.5 Lateral Support Partial Length Core Tests

Dynamic tests were performed on the simulated NRX-A6 lateral support system that was previously used for static and axial leakage tests. The test assembly consisted of four rows of lateral support reactor grade hardware and a

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FIGURE 3a
TEST SPECIMEN OF
LASL MATERIAL(75X)
EML- C.1

FIGURE 3b
TEST SPECIMEN OF
CARBORUNDUM MATERIAL (200X)
EML-C.1

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solid core installed in an aluminum reflector ring. The lateral support hardware included seal segments, plunger pins, latches, sleeves with seals, springs, retaining caps and "O" ring seals of the present A6 design.

The latch arrangement was different from that of previous tests to evaluate the possibility of reducing the number of latches. The location of the latches for the dynamic tests is shown in Figure 4. The two rows at the nozzle end were unchanged from the static and leakage tests. The latches in the third row from the dome end were locked with a commercial compound "Loctite". Because of the difficulty in locking the molybdenum latches, only the inconel latches were crimped with a staking tool. Also, twenty-four wedge rings were installed on the spring retaining caps in the second row from the dome end.

The test arrangement is shown in Figure 5. The solid graphite core weighing 560 lb was suspended by a steel cable. Encircling the core and mounted on four oil film slip tables to insure unidirectional motion was the aluminum reflector containing the lateral support system. Two 10,000 lb thrusters were used to vibrate the assembly in the frequency range of 500 to 5 cps to an acceleration level of 5 g's. Three accelerometers were bolted to the core to record motions. One was oriented in the horizontal direction in line with the thrusters and two were mounted vertically. The sweeps and dwells are shown in Table III.

One of the two accelerometers attached to the aluminum reflector was used to control the applied forces. Strobe lights were synchronized so that a visual examination could be made of the relative displacement between the core and fixture plate. Inspection after testing showed that the core rotated clockwise approximately 45 degrees during the duration of testing. The data obtained during testing will be analyzed during the next period.

EML-E.2 Friction Tests of Reactor Components

Friction tests of unfueled NbC coated partial element and uncoated graphite "G" specimens were conducted to support Design and Stress Analysis groups in their evaluation of the NRX-A6 filler strip concepts. Five simulated reactor

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FIGURE 4
 LOCATION OF LATCHES
 EML-D.5

FIGURE 5
 LATERAL SUPPORT SYSTEM
 TEST ARRANGEMENT
 EML-D.5

TABLE III

PARTIAL LENGTH CORE VIBRATION TEST - EML-D.1

Run No.	Test	Frequency cps	Acceleration Level (g)	Duration	No. of Cycles (1000 cycles)
1	Sweep	500 to 8	2	5 min.	64
2	Sweep	500 to 8	2	5 min.	133
3	Sweep	500 to 200	3	2 min.	26
4	Sweep	10 to 20	3	2 min.	8
5	Sweep	500 to 8	2	5 min.	76
6	Sweep	500 to 11	3	5 min.	53
7	Sweep	500 to 12	4	5 min.	51
8	Dwell	100	2,3,4,5	5 sec. ea.	6
9	Dwell	95	2,3,4,5	5 sec. ea.	3
10	Dwell	90	2,3,4,5	5 sec. ea.	2
11	Dwell	85	2,3,4,5	5 sec. ea.	2
12	Dwell	80	2,3,4,5	5 sec. ea.	2
13	Dwell	75	2,3,4,5	5 sec. ea.	2
14	Dwell	70	2,3,4,5	5 sec. ea.	2
15	Dwell	65	2,3,4,5	5 sec. ea.	2
16	Dwell	60	2,3,4,5	5 sec. ea.	1
17	Dwell	55	2,3,4,5	5 sec. ea.	1
18	Dwell	50	2,3,4,5	5 sec. ea.	1
19	Dwell	45	2,3,4,5	5 sec. ea.	1
20	Dwell	40	2,3,4,5	5 sec. ea.	1
21	Dwell	35	2,3,4,5	5 sec. ea.	1
22	Dwell	30	2,3,4,5	5 sec. ea.	1
23	Dwell	25	2,3,4,5	5 sec. ea.	1
24	Dwell	20	2,3,4,5	5 sec. ea.	1
25	Dwell	15	2,3	5 sec. ea.	1
26	Dwell	10	2	5 sec. ea.	1
27	-	-	-	-	-
28	Sweep	500 to 39	4	5 min.	51
29	Sweep	500 to 10	3	5 min.	33

Total 527,000
cycles

test runs of ten minute duration each were conducted in an atmosphere of hydrogen.

Test conditions and significant results are summarized in the following table:

Test Temperature °R	Contact Pressure Psi	Static Coefficient of Friction or Breakaway Force*	Results
3500	10	.62	No significant wear of con- tact surfaces was revealed by post-test visual inspection of specimens.
4500	10	2.0*	
1500	100	.17	
2500	100	.35	
4500	100	.96	
4500	150	.95	

*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 specimen in contact.

EML-E.3 Aft End Flow Impedance Seal Evaluation

Flow tests were conducted in the partial length, seven cluster core model without impedance seals on the elements. Pressure probes were installed in the assembly to map the interelement pressure distribution. Although analysis of the data is not complete the pressure probe data indicates normal distribution. Figure 6 shows a top view of test core with pressure probes in place.

The installation of the pyrofoil impedance seal sleeves on each element of the central clusters was completed. The test core with the sleeved clusters is now being assembled. The model will then be installed in a pressure vessel with a rubber bladder bundling system to perform comparative flow tests. Figure 7 depicts elements with sleeves cemented at aft end.

Behavior of the pyrofoil sleeve material under compressive loading must be known in order to specify undercut tolerances on the core element. One test was performed on a 20-layer stack of 2 x 4 in. pyrofoil sheets. The results indicate that for low loading conditions of five psi, permanent compaction of approximately 0.0002 in. per layer is possible under the tamping action during sleeve installation. To provide more statistical compaction data, additional tests are planned on foil sheets which have been precompressed by application of five psi pressure.

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FIGURE 7
FUEL ELEMENTS WITH AFT END IMPEDANCE
SLEEVES EML-E.3

FIGURE 6
FLOW IMPEDANCE TEST RIG
WITH SEAL EML-E.3

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TFL-2. c Plunger Pin Capsule Seal Tests

It is planned to test NRX-A7 designed seals for use in the NRX-A6 reactor. Fourteen seals will be flow tested in pairs under the following test conditions.

Mediums:	Helium and Hydrogen Gas
Temperatures:	Ambient and Cryogenic
Cycling:	Not required but may result from two levels of test temperatures
Pressure Differentials:	15, 100, and 200 PSID

The 15 and 200 PSID represent the extreme reactor conditions. The 100 PSID is for comparison with previous tests of the old seal design.

A mechanical test, using 140 lb radial load on the sleeve, will be applied 12 times between the ambient and cryogenic tests.

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NRX-A7 TESTS

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TFL-2. c Plunger Pin Capsule Seal Tests

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The 15 and 200 PSID represent the extreme reactor conditions. The 100 PSID is for comparison with previous tests of the old seal design.

A mechanical test, using 140 lb radial load on the sleeve, will be applied 12 times between the ambient and cryogenic tests.

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NR-1 TESTS

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TFL-2. d Plunger Pin Capsule Flow Impedance Tests

The test fixture, with the capsule envelope nominally offset 0.030 inch from tangency to the centerline of the coolant passage, was tested and the data reduced. The loss coefficient, based on the coolant passage cross sectional area, was 0.232 across the center plunger pin. Data for this test and previous tests is presented in Figure 8. There is no activity planned in this area for the next period.

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FIGURE 8

NR-1 PLUNGER PIN CAPSULE FLOW
 IMPEDANCE TEST FIXTURE AND RESULTS

EML-A.4 Ganged Drum Titanium Band Test

Specimens to be used for determining the mechanical properties of the titanium band at ambient and cryogenic temperatures are being fabricated. The tensile specimens are being made from the first lot of bands received from the Materials Department. These bands are not suitable for the full band tests but short sections appear acceptable for the materials property evaluation.

EML-C.4 Anti-Criticality Poison System

A series of tests are being planned for the evaluation of the poison wires during removal from the fuel elements. Procurement of the poison wires and fabrication of the test fixture has been initiated. Scheduling of the tests is dependent upon fabrication of the poison wires.

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TFL-5. b Interstitial Corrosion Tests

Tests to study the corrosion rate of stabilized and unstabilized pyrofoil in reactor configurations were conducted. The first test consisted of two 5 mil thick stabilized pyrofoil specimens set in windows which bordered on an 0.0008 inch thick, 0.445 inch wide flow slot.

This configuration simulated one flat of the aft end impedance sleeve system. The specimen was tested at 3500°R for 30 minutes with a hydrogen pressure of 350 psig and flow of 1.2×10^{-5} lb/sec. A low specimen pressure drop during the test indicated a leak in the system which was confirmed on disassembly. The leak was located in a threaded area of the molybdenum hardware. As a result of the leak, the flow through the slot was reduced to a point that produced small amounts of corrosion on the inlet edges of the slot. The hydrogen was sufficiently contaminated with hydrocarbons, by the time it reached the pyrofoil, that no reaction with the pyrofoil was visible. Another specimen has been prepared but is being coated on all surfaces to prevent contamination of the inlet gas.

The two other tests simulated a 0.010 inch thick non-thermalized and thermalized pyrofoil wrapper in contact with a coated filler strip gap. The gap was 0.280 inches deep and 0.006 inches thick, all surfaces of the fixture were coated so only the pyrofoil was directly exposed to the hydrogen. Each fixture was tested at 3500°R with a hydrogen inlet pressure of 350 psig and a flow of 4.3×10^{-5} lb/sec for 30 minutes.

The test conditions and results are given below:

Test Number	TFL-5. b. 031	TFL-5. b. 032
Test Time (min)	30	30
Inlet Pressure (psig)	350	350
Inlet Gas Temperature (°R)	525	524
Outlet Gas Temperature (°R)	1626	2151

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Inlet Material Temperature ($^{\circ}\text{R}$)	3498	NG
Outlet Material Temperature ($^{\circ}\text{R}$)	3492	3501
Flow Rate (lb/sec- H_2)	4.3×10^{-5}	4.27×10^{-5}
Graphite Specimen Weight Loss (gms)	.073	.080
Pyrofoil Specimen Weight Loss (gms)	.0405	.077

Figure 9 shows the thermalized specimen upon disassembly and the condition of the specimen surfaces with the pyrofoil removed. Figure 10 shows a close-up of the pyrofoil in the specimen window and the pyrofoil corrosion in relation to a scale so the corrosion widths can be measured.

Figure 11 shows the non-thermalized specimen in the fixture window and the condition of the fixture with the pyrofoil removed. Figure 12 shows magnified views of the pyrofoil positioned in the fixture window and with a scale so the corrosion widths can be measured.

Figure 13 shows the non-thermalized pyrofoil specimen compared to one that has not been tested. The corrosion comparison on a weight basis shows the thermalized material to have a higher resistance to corrosion than the non-thermalized material. Some of the weight loss difference could be attributed to the out-gassing of the non-thermalized material; however, visual comparison between Figures 9 and 12 show that the non-thermalized pyrofoil did lose more material.

TFL-5. c Reactor Graphite Component Permeability Tests

Additional analyses were completed on the data presented in WANL-TME-1557, Figures 15 and 16 for the Development Test Program Review Meeting held December 21, 1966. It was found that good correlation could be obtained between the ambient helium tests and the four tests conducted with various temperature profiles - maximum levels of 2665°F , 3321°F , 3901°F , and 4411°F . The correlation was obtained by using an incremental summation of the D'Arcy

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FIGURE 9

THERMALIZED PYROFOIL SPECIMEN AFTER TEST

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FIGURE 10
CLOSE-UP OF THERMALIZED PYROFOIL SPECIMEN AFTER TEST

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FIGURE 11

NON-THERMALIZED PYROFOIL TEST SPECIMEN AFTER TEST

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FIGURE 12

CLOSE-UP OF NON-THERMALIZED PYROFOIL SPECIMEN AFTER TEST

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UNTHERMALIZED PYROFOIL

INCHES

1

2

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mm

10

20

30

40

50

FIGURE 13

TESTED UNTHERMALIZED PYROFOIL SPECIMEN
COMPARED TO UNTESTED SPECIMEN

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parameter of the form $\sum_{\mu} \frac{1}{T}$ where T is the temperature for the incremental length and μ is the viscosity at the temperature. In addition, good correlation with the above was obtained on an ambient hydrogen test at 600 psi and pressure differentials from 2 - 90 psid.

An additional test was conducted with helium at four temperature levels ranging from 3100°R to 4870°R. The purpose of these tests was to investigate the types of profiles obtainable in the facility. Testing will continue next period.

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EML-B.1 Permeability of Fuel Elements at Temperature

Five elements were tested to determine the permeability at high temperature. These elements complete the planned tests of A5 type elements with varying coating thicknesses at Station 20. Data has been reduced on three of these elements, one WANL element with 1.5-2 mil coating at Station 20 and two Y-12 elements, one uncoated and one coated. During the last period a computer program was completed that will allow us to reduce the lag between testing and plotting of the curves. This will be in use before the next meeting.

Data from the WANL element tested are shown in Figure 14 showing the leakage flow rate in lb/hr/inch versus temperature for the various pressure conditions used in the test. This element developed a pinhole shortly after testing at 3000°R. There is an indication that this occurred when the differential pressure reached 40 psi at 3000°R. At this point the leakage flow increased slightly as the pressure was increased. This test is normally conducted by setting the temperature of the specimen, then increasing the differential pressure from 10 psi to 20 psi, 30 psi, etc. taking data at each pressure increment. The pressure is then reduced to 10 psi or less before going to the next temperature increment. By the time the specimen was at 4000°R, differential pressures above 30 psi already indicated a gross change in the leakage flow and the test was discontinued. Post-test examination of the specimen revealed the pinhole shown in the photograph on Figure 15. Note that the pinhole is about 1/2 inch from the coated end of the element which is shown still installed in the test fixture.

Figure 16 is a curve of the leakage flow versus temperature for the Y-12 uncoated element. This element had a very low flow rate despite the absence of coating. For comparison, Figure 17 is a plot of the leakage flow versus temperature for four WANL elements of various coating thicknesses and two Y-12 elements. Curves A, B and C are for elements with coating thicknesses of 1.5-2.0 mils at Station 20 and Curve E represents a WANL element with 1.0-1.5 mil coating at Station 20. Curve D and F are for the Y-12 uncoated and coated, respectively.

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Permeability Test of Fuel Element No. PP-20064
 Leakage Flow Rate Versus Temperature for Constant Pressure Parameters

Customer's Parameters:
 P_0 = Absolute Pressure, psia
 ΔP = Differential Pressure, psia

Curves shown for:
 $\Delta P=0, P_0=70$
 $\Delta P=0, P_0=60$
 $\Delta P=10, P_0=50$
 $\Delta P=10, P_0=40$
 $\Delta P=20, P_0=30$
 $\Delta P=30, P_0=20$
 $\Delta P=40, P_0=10$
 $\Delta P=50, P_0=10$

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FIGURE 16
 PERMEABILITY TEST OF Y-12 FUEL ELEMENT NO. 99-78648
 EML-B.1

FIGURE 17
 PERMEABILITY TEST RESULTS
 EML-B.1

Data from these tests is being examined periodically as an aid in defining constants for Darcy's permeability equation. Plots for Darcy's constant (K) versus temperature are shown in Figures 18 and 19. Figure 18 is a plot for one of the WANL elements with a 1.5-2.0 mil thick coating at Station 20. Note the drop-off in the constant for temperature above 4000°R and the change in the value of the constant with pressure. Figure 19 is a similar plot for the Y-12 uncoated element. This curve has the same general shape with a decrease in K above 3500°R. The values of the constant are generally lower for the Y-12 elements than the WANL elements although both change markedly with pressure as well as temperature. These curves indicate that there is much to be done to fully understand this data. Testing to date has also shown some marked differences between elements as well as coating thicknesses.

Figure 20 is a plot of the leakage flow per unit length for three WANL elements versus normalized data in the form $\frac{\bar{P} \Delta P}{\mu R T}$. All of these data points are in good agreement as shown by the plot, however, the slope of this line indicates that the exponent is on the order of 0.72 instead of 1 that is generally used in Darcy's equation.

Current work consists of testing of a WANL uncoated element with both helium and hydrogen. The helium run has been completed and data is currently being reduced. This will be followed by a similar test using hydrogen so that the constant (K) can be plotted for both gases. In addition, a series of moly-coated elements are expected to be completed before the next meeting. One of these has been received with a 1.5-2.0 mil thick coating at Station 20 and will be tested next period.

EML-E.1 Core Periphery Temperature Tests

a. Core Wrapper Strain Tests

A total of eighteen high temperature expansion tests were conducted in which proposed pyrofoil wrapper material was exposed to strains varying from approximately 0.8 to 1.3 percent. The non-stabilized pyrofoil survived

FIGURE 18
DARCY'S CONSTANT (K) VERSUS TEMPERATURE FOR
COATED WANL ELEMENT No. 99-26627
EML-B.1

FIGURE 19
DARCY'S CONSTANT (K) VERSUS TEMPERATURE FOR
Y-12 UNCOATED ELEMENT No. 99-78648

FIGURE 20
FLOW PER UNIT LENGTH OF ELEMENT
VERSUS THE PARAMETER $\frac{\bar{P} \Delta P}{\mu R T}$
EML-B.1

the maximum strain in both the lengthwise (rolling) and crosswise direction. In one test, the temperature was cycled from 1900 to 4500°R three times. The time of the warmup cycle was 40 to 45 minutes while the cooldown cycle was 35 to 40 minutes. The maximum strain was approximately 45 percent greater than that anticipated in the material if exposed to reactor conditions.

All of the stabilized wrapper specimens failed when exposed to the maximum strain in the lengthwise direction. When strain was imposed in the crosswise direction; however, the stabilized grade survived the maximum expansion tests. As a result of these tests the specification for reactor grade pyrofoil has been revised to include the non-stabilized material. Figure 21 shows the pyrofoil wrapper specimens after testing.

b. Core Wrapper Peripheral Temperature Tests

The core periphery test assembly with pyrofoil wrapper was used to run a 50 psi test with one mil gaps between the filler strips. Mylar tape was used to hold the pyrofoil in place so that this proposed assembly technique could be evaluated under reactor temperature conditions. The test reached a temperature of 3000°R and a differential pressure of 50 psi across the core when the container holding the graphite test specimens failed. Post-test examination showed no depression of the foil at all and raised the question as to whether the 30 psi was the true differential across the six layers of pyrofoil. As a result of this test two specific actions were taken: (1) communication holes were added to the next build to insure that the full pressure drop across the core section was the same across the foil, and (2) a small additional room temperature pressure test was designed and built to allow testing to higher pressure drops across the foil spread over a 300 mil gap. This test will use a 300 mil gap six inches long and should be completed in the next period.

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FIGURE 21
CORE WRAPPER SPECIMENS AFTER TESTING
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The next build of this test series included additional insulation and filler strips for gaps of 100, 150, 200 and 300 mils between selected strips. The additional insulation was added to improve the heat distribution of the assembly and prevent failure of the container that occurred in the previous test. The build also included communication holes to these gaps to insure that the pressure drop across the foil was the same as the pressure drop across the periphery. This test was run at 30 psi to a temperature of 3000°R on the filler strip. The test showed that the layer of foil closest to the gap deflected approximately 40 mils into the 300 mil wide gap with some smaller deflection into the 200 mil gap. Negligible deflection was observed in both the 100 and 150 mil gaps. The other five layers of foil deflected considerably less. There was no evidence of tearing or other failure in any of the pyrofoil layers. This test showed that temperature is important for deflection of the foil into wide gaps. The container on this test cracked in a completely different manner and is more indicative of mechanical failure than was seen before indicating improved heat distribution. This container has been redesigned and fabrication of spare components has been initiated.

c. Filler Strip Strength and Thermal Gradient Tests

The test effort during this period was in the area of tensile tests and thermal gradient tests on Graphitite "G" and filler strip specimens. Eleven tensile specimens had been tested to determine the fracture strain of the Graphitite "G" material. These showed fracture strains varying from 2260×10^{-6} in./in. to 3220×10^{-6} in./in. giving ultimate strengths between 3000 and 5000 psi for this material. In addition, flexural tests on filler strip geometries were also completed. These confirmed the results of the tensile tests with fracture strains that varied from 2290×10^{-6} in./in. Recently, bundling tests have also been set up to test A6 filler strips.

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These tests used the same bundling arrangement previously used to determine the tensile strain of fueled elements except that solid elements were used on either side of the filler strip specimens instead of a cluster. A single check-out test has been completed up to this point and showed a fracture strain of 2300×10^{-6} in./in. Additional tests will be completed during the next period.

To support the filler strip evaluation, a thermal gradient test of a two inch diameter specimen of Graphitite "G" was conducted. A stainless steel tube was passed through a hole in the center of the specimen and cemented in place. The water-cooled tube was used to remove heat from the center of the Graphitite "G" material while the specimen was heated radially on the O.D. when installed in a furnace. Three thermocouples provided a measure of the gradient on the radius during this test. The objective of the test was to get the maximum gradient possible across this section and a gradient of 1800°R was obtained. Analysis showed that this gradient resulted in a stress on the order of 3700 psi. Photographs of the sectioned specimen are shown in Figure 22. Note that the crack does not penetrate the outer surface and was not noticed until after sectioning.

EML-H.2 Component Acoustic Tests

Fuel element test specimens are being prepared for the second series of acoustic tests. These specimens are being weighed, porosity checked and bore replicated. The next step of pre-acoustic test evaluation will be a channel blowdown to determine bore coating adherence. The data obtained from these evaluations will be compared with similar measurements taken after the testing is completed.

Studies are being made to determine the susceptibility to induce bore coating cracks during handling and cutting operations. The results of these studies will aid in determining the feasibility of testing partial length elements in place of the present full length elements.

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FIGURE 22
GRAPHITITE "G" SPECIMENS
AFTER TESTING
EML-E.1

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Work was completed on the guard heater power supply.

Work on the data trailer is proceeding on schedule. The data acquisition equipment has been removed from the building at WANHES and is being relocated in the trailer.

A summary of the AEC capital equipment line items, Nos. 226 through 230, with a total value of \$116,000.00 is as follows:

Total committed	\$ 90,410.00
To be used for installation of 1.5 power supply	12,800.00
Balance to be committed	<u>12,790.00</u>
	\$116,000.00

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