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March 17, 1967

Westinghouse Astronuclear Laboratory

NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW MEETING
HELD WITH SNPO AT WANL ON MARCH 2, 1967
(Title Unclassified)

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Westinghouse Electric Corporation
Astronuclear Laboratory
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SPECIAL REREVIEW FINAL DETERMINATION	Reviewers	Class.	Date
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Classification cancelled for change to
by authority of Doc
by 187.c. TIC, date SEP 10 1973

E. A. DeZuboy, Manager
Thermo-Flow Laboratory

W. J. Rowan, Manager
Engineering Mechanics Laboratory

INFORMATION CATEGORY

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NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW MEETING
HELD WITH SNPO AT WANL ON MARCH 2, 1967

Attendees:

DeZubay, E. A.	WANL	Kelly, V. G.	WANL
Fisch, J. W.	WANL	Olinger, J. S.	WANL
Fix, H. J.	WANL	Rieb, M.	AGC
Havener, W. J.	WANL	Rowan, W. J.	WANL
Helms, I.	SNPO-W	Schreiber, J. J.	WANL
Hoffman, H.	SNPO-C	Tauch, F. G.	WANL
Kalvin, G.	SNPO-C	Thompson, D. C.	WANL
Kanter, I. E.	WANL	Watjen, E. A.	WANL

The Monthly Development Test Program Review Meeting was held at WANL on March 2, 1967.

It was agreed that the next monthly review meeting would not be held due to prior commitments. In place of this meeting, a draft reviewing the development test program during this period would be reviewed with G. Calvin at WANL on April 17, 1967.

Lists of the tests performed during the month of February 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.

TABLE I
THERMO-FLOW LABORATORY TEST SCHEDULE

PERFORMED THIS PERIOD

PLANNED NEXT PERIOD

Tests for NRX-A6	
TFL-1.a Cluster Tests	
1.a. 0006a-d Regular Developmental Composite Protection Cup	Exit Gas Thermocouple
4 Cycles - 23'; 23.5'; 0; 19' = 65.5'	Tungsten Cup - Irregular
1.a. 0007a-b Regular Developmental Tungsten Protection Cup	
2 Cycles - 30+28 = 58'	
TFL-1.b Single Element Tests	
208 Tests - WANHES, Phases III and IV, and PAX	Continue Testing
30 Tests - WANL, Phase II-1B, "X" Coat	
TFL-2.a Filler Strip Test	Continue Test Model Component Procurement and Build
TFL-2.c Plunger Pin Capsule Seal Tests - Initiated Testing	Continue Testing
TFL-4.e Reactor Seal Test - Forward End - Initiated	Completed
TFL-6.a 360° Reactor Shield - Completed	No Activity
TFL-6.b Filler Strip Plugs - Initiated Testing	Continue Testing
General Development	
TFL-1.a Cluster Lateral Support Model	Procure Hardware
TFL-1.b Water Injection Design in Process	Long Hot End Chuck
High Power-High Flow Tests	Nine Inch Isothermal Test
	Continue High Power-High Flow Tests
TFL-5.b Interstitial Corrosion - Four Tests	Continue Testing
Facilities	
DAS Trailer	

TABLE II
ENGINEERING MECHANICS TESTING
PERFORMED THIS PERIOD (Feb.) PLANNED NEXT PERIOD (March)

Tests for NRX-A6	
EML-C.1 Support Washer Load Tests Additional Carbide Cup Tests Tungsten Irregular Cup Tests	EML-C.1 Continue Testing Continue Testing
EML-D.5 Evaluation of Lateral Support Partial Core Dynamic Tests	EML-D.5 Lateral Support Dynamics Tests Simulating A6 Full Core Motion
EML-E.2 Friction Coating and Wear Tests	EML-E.2 Continue Friction Tests
EML-E.4 Filler Strip Keyway Strength Tests	EML-E.4 Filler Strip and Filler Tile Tests
NR-1	EML-A.4 Tensile Tests Ganged Drum Band Specimens
General Development	
EML-A.1 Insulating Cylinder Three-Fastener Tests	
EML-B.1 Fuel Element Permeability Tests at Temperature	EML-B.1 Continue Fuel Element Permeability Tests
EML-E.1 Core Periphery Pyrofoil Wrapper Tests Graphite "G" Thermal Gradient Tests	EML-E.1 Additional Pyrofoil Wrapper Tests
EML-E.3 Aft End Flow Impedance Tests with Pyrofoil Seal Sleeves	
	EML-H.2 Pre-test Evaluation of Acoustic Test Components
Facilities	
Checkout Run of Thermal Gradient Facility	

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TESTS FOR NRX-A6

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TFL-1.a Single Cluster Development Tests

The third and fourth cycles of the test to evaluate a developmental composite protection cup were conducted during the period January 26, 1967 through March 1, 1967. The two previous cycles were described in WANL-TME-1569. The composite cup is composed of 75% NbC and 25% carbon. The third cycle was terminated during start-up as a result of arcing at the cold end chuck. A temperature of 3700°R exit gas temperature was attained prior to shut-down. The fourth cycle was successfully completed and terminated by a normal shut-down. The test operated for a period of 19 minutes at a 4300°R exit gas temperature. This made a total cumulative test time, on the composite cup and block at 4300°R, of approximately 66 minutes. Post test examination revealed very slight damage to the composite cup and skirtless block. There were a few hair-line cracks on the cup and block and the corners on the inner face of the block were chipped and corroded.

The second and third cycles of the test to evaluate a developmental tungsten protection cup were conducted during the period January 26, 1967 through March 1, 1967. The cup was composed of vapor deposited tungsten. The second cycle included a normal ramp to full power and temperature followed by an automatic test termination as a result of a current overload in the power supply (18,200 amperes). The third cycle was successfully completed and terminated by a normal shut-down. The flow rate of hydrogen was reduced to 0.12 lb/sec to reduce the power load and prevent the overloading of the power supply. The total test time, including all transients, was about 60 minutes. No visual damage was observed. The coating on the pyro washer and tungsten protection cup looked very good. Post test inspection is in progress. It was also noted that all skirtless blocks used in these tests have held up very well. It is planned

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to conduct three 20 minute cycles on an exit gas thermocouple in the near future. It is also planned to conduct proof tests consisting of three 20 minute cycles on metallic protective cups for irregular blocks.

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

There were 208 elements tested at WANHES during the period January 26, 1967 through March 1, 1967. Of the 208 elements tested, 18 were PAX elements and the remaining 190 were part of Phases III and IV of the Fuel Element Assessment Program. There were 30 single element tests conducted at WANL during this same period. Using the parameters from 26 of these tests, an analysis of variance was made through a linear regression model based on the gross weight loss of the elements. The results showed that by using this analysis, test time, power level and power/flow ratio effects could be separated. The effect of exit pressure; however, could not be isolated. Testing with higher power (up to 1.3 MW) and flows (up to 810 scfm) was started and will be continued during this next period.

TFL-2. a Filler Strip Corrosion Tests

Work is continuing on defining the test model for the next filler strip corrosion test. The new model design is expected to incorporate anti-friction slippage liners, an uncoated inner core, filler strips coated on the outside surface only and eight layers of pyrofoil between the filler strips and tile. As of March 1, 1967, the mechanical design phase of the model is approximately 90% complete. The thermal and hydraulic analysis is in progress to determine the seal system flow rate. Some of the hardware has already been received and if there is no delay in getting the filler strips coated, the test should be completed on schedule.

TFL-2. c Plunger Pin Capsule Seal Tests

Fourteen seals of the proposed NRX-A7 design were tested for leakage, Figure 1. The test conditions were ambient temperature and 100 psig helium

FIGURE 1
PLUNGER PIN CAPSULE SEALS

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differential pressure across the seals and an assembly torque of 150 in. lbs. The leak rate for these seals ranged from less than 1×10^{-4} scc/sec to 2.3×10^{-2} scc/sec. A relaxation of the A6 seal requirements may permit the old design to be used. In line with this, 12 seals of the double diamond NRX-A6 design, that were rejected previously for improper seating angle, were tested. The seals were tested with 100 psig helium to atmosphere across the seals and a seating torque of 150 in. lbs. was applied to the capsule. The leak rate for these seals ranged from 0.0228 to 2.84 scc/sec. A revision in the seal program resulted in a modified NRX-A6 double diamond seal. The seal was modified by removal of the flange on the outside of the seal; thus changing the outer diamond to a triangular shape. Five sets of these seals, relatively free of flaws, were tested with helium gas at ambient temperature and a 100 psi differential pressure across the seal. The leak rate of these seals ranged from 5×10^{-6} to 6×10^{-4} scc/sec. A severely surface marred seal was also tested under these conditions and found to have a leak rate of 1.4×10^{-2} scc/sec. If these seals can be considered an adequate sampling of the three seal configurations proposed, the modified NRX-A6 seals are far superior to the other two. It is planned to conduct radial load and cryogenic tests in the next period.

TFL-4. e

Reactor Seal Tests

Three tests were conducted on the reactor forward end seal which is located between the core support plate and the shield. These tests were conducted using ambient hydrogen at nominal pressure levels of 500 and 700 psig and with seal deflections of 15, 93, and 243 mils. The data obtained from the tests was very consistent within the seal pressure drops common to a particular inlet pressure. There are no further tests anticipated at this time.

TFL-6. a 360° Reactor Shield Test

Final tests were conducted using diesel fuel smoke. The tests verified that ingestion will not occur with the hooded duct and ring manifold system as long as the minimum ratio of ring to duct flow is 0.26 to 1; however, without a hooded duct, the minimum ratio must be approximately 3.5 to 1. This completes the testing in this area.

TFL-6. b Filler Strip Plug Tests

Filler strip plug tests were conducted on specimens which consisted of 1-1/8 inch long coated filler strip samples containing a coolant passage. The coolant passage was plugged by means of a plug, the axis of which was at right angles to that of the coolant passage. The back of the plug and the side of the plug exposed on the aft end of the coolant passage were sealed with zirconium foil which had melted and carbided to produce the seals. The specimens were placed in the fixture and the forward end of the fixture was pressurized with helium gas at ambient temperature and 10 psig, Figure 2. The aft end of the strip was sealed with a flat gasket while the area around a jet orifice supplying the helium was sealed with an "O" ring. It can be concluded that the plug is as effective a seal as can be designed considering the porosity of the filler strip.

The leak rates for each of the three specimens were:

Specimen Number	Plug Leak Rate (cc/min)	Coolant Hole Leak Rate (cc/min)	Porous Flow Rate From Element Section (cc/min)
51	2.475	0.70	11.40
52	3.310	1.05	12.45
53	3.100	0.000	15.00

It is planned to continue this test program using full length filler strips.

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FIGURE 2

TEST FIXTURE FOR 1-1/8 INCH LONG SPECIMENS

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EML-C.1 Support Block Hardware Tests

a. Coated Support Washer Tests

Tests of coated support washers were conducted to determine deformation under load and permanent deformation both at room and elevated temperatures. Both tungsten and carbide composition cups react their loads to the support block through support washers which allow only a few mils separation from the rim of the cup to the face of the block. Washers were tested under repeated and increasing loads between parallel flat surfaces and the measurement taken.

Each washer tested at a temperature of 4300°R incurred permanent set characterized by a decrease in thickness and an increase in diameter. These dimensional changes averaged 0.6-0.8 mils in thickness for 700-800 lb loading and were about the same whether at temperature for ten minutes or an hour. The O.D. increased 0.2-0.3 mils under the same conditions. Stepping up the load to 1000 and 1200 lb produced further permanent deformations amounting to a total of 1.8 mils in thickness. At room temperature a 2000 lb load reduced the washer's thickness 3.6-4.3 mils with about 0.3 mil permanent deformation.

Coating cracks were noted in the washers after test. In all cases these were circumferential around the inner surface. In the high temperature tests there were additional radial cracks around the peripheries of the outside corners.

b. Carbide Cups

A carbide composition cup of LASL 75 percent NbC-25 percent Graphite material was retested at 1800 lb loading in the furnace at 4500°R. The cup had been tested under similar conditions previously with loadings at 200 lb intervals starting at 800 lb. A peripheral crack in the ledge which was noticeable after the 1200 lb loading was defined more sharply but no structural failure of the cup was apparent.

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c. Tungsten Cups

Three vapor-deposited tungsten cups from experimental early runs of material were loaded to 800 lb and tested for one hour at 4500°R. Hydrogen gas was passed through the specimens at five scfm. A blackening and cracking of the tungsten surface occurred during testing. This was subsequently found to be the result of contaminants from pre-test polishing of the test specimens. The third cup underwent no surface damage but metallographical examination revealed a layer of carbide. A blistering of the inner surface was noted on all three cups. In general, it has been felt that the earlier samples of tungsten vapor deposition are not suitable to base any conclusions on relative to performance at temperature.

EML-D.5 Lateral Support Partial Length Core Tests

An evaluation was made of the dynamics tests that were conducted on the simulated NRX-A6 lateral support system. The test assembly consisted of four rows of lateral support reactor grade components and a solid core installed in an aluminum reflector ring. The dynamic testing included a frequency range of 500 to 5 cps to an acceleration level of 5 g's.

Figure 3 is a schematic showing the direction of drive through the partial core assembly and the orientation of seal segments and pins.

Figure 4 shows the dome end prior to disassembly. The inner seals can be seen to have shifted, leaving gaps between inner seal segments 1 and 2. A similar stacking of tolerances occurred between seals 7 and 8. The lips of the seal segments can be seen to be in contact with the even number of pins in the as-designed condition.

The plunger pins, spring retaining cups, springs, inner seal segments and the solid graphite cylinder which simulated the reactor core were disassembled from the aluminum reflector. Damage to the pins, inner and outer seals was noted especially in the areas around the force input at 0 to 180 degrees.

FIGURE 3
EML-D.5

FIGURE 4

LATERAL SUPPORT ASSEMBLY AFTER
TESTING (EML-D.5)

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Minimum wear marks were noticed around 90 and 270 degrees as expected. Figure 5 shows the condition at 90 degrees and Figure 6 shows the condition at 0 degrees.

The broken particles in Figure 6 are from three broken pins digging into the surface of the seal segments. There is a possibility that the pin and seal segment damage was the result of improper positioning of the pins or seals. This has resulted in adding view holes in the spring retaining cups to visually and mechanically inspect the position of the pins after assembly in the reactor.

The wave shapes of the five accelerometers measuring motions of the core and reflector indicated that the damage most likely occurred during the 4 g sweep from 500 to 12 cps. The natural frequency of the system occurred at approximately 20 cps. The maximum acceleration level is limited to 1 g during shipping of the reactor to the test site.

An analysis was performed in which the mathematical model of the reactor indicated that the center of pitching of the core occurs at approximately 52 inches from the nozzle end of the core. This showed that the approach of supporting the core with one cable through the center of gravity used in the test arrangement was conservative. Therefore, the test will be rerun with an axial supporting system simulating the restraining pitching action of a full core.

The design was completed and fabrication started on a test fixture which will constrain the partial length core to pitch around center as determined from the analytical model. Also an evaluation of a possible support of the reflector is being made to better simulate reactor conditions. Testing is presently scheduled to be initiated during the next period.

EML-E.2

Friction Tests of Reactor Components

Tests of pyrofoil, as a sliding interface between uncoated graphite "G" filler strip and NbC coated unfueled partial element were performed in hydrogen to determine the friction and wear that would occur during simulated reactor

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FIGURE 5
OUTER SEAL SEGMENTS AT 90° AFTER TESTING
EML-D.5

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FIGURE 6
OUTER SEAL SEGMENTS AT 0° AFTER TESTING
EML-D.5

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test runs. A simulated reactor run consists of simultaneously initiating the relative motion between specimens and bringing up the temperature to the steady state condition desired. The steady-state condition can usually be attained in approximately three minutes. A ten minute hold at steady state and then initiation of the return motion cycle and return to ambient temperature completes one simulated reactor test run. The tests during the month were conducted primarily to evaluate the effect of Armstrong C-7 cement used to attach the pyrofoil to the filler strips as a proposed assembly aid. In every test, where the C-7 cement was used, a stick slip phenomenon occurred at approximately 3000°R on the initial motion and temperature ramp. The coefficient of friction at this condition varied from .28 to .41.

The tests were conducted at 4400°R with the exception of run no. 1 which was at 3300°R. Also the contact pressure was 93 psi except during run no. 3 which was at 35 psi. The other test conditions and results are presented in Table III.

EML-E.4

Core Periphery Element Support

A test program has been initiated to evaluate the load capabilities of components in the A6 peripheral design concepts. There are five areas being considered under this program.

- a. Shear Strength Test of Filler Tile and Filler Strip Ledge
- b. Filler Strip Keyway Strength Tests
- c. Axial Load Capability of Support Block Ledges
- d. Filler Strip Failure Due to Radial Pushout of Orifice Meters
- e. Cluster Plate Tilting Characteristics

Testing was initiated to determine the ultimate shear load of filler tile of 92 mil thickness due to a relative movement of adjacent filler strips. In a single test, the filler strip ledge failed as shown in Figure 7. The test assembly is shown in Figure 8. The test plan therefore, has been revised to test the ledges of certain continuous pairs of filler strips. Also the latest design of filler tile with 81 mil thickness will be used. In the remaining four areas of the program, test hardware is presently in the procurement stage.

TABLE III

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<u>Specimens</u>	<u>No. of Cycles</u>	<u>Coeff. of Static Friction</u>	<u>Results</u>
1) 0.003 pyrofoil between the graphitite "G" filler strip & NbC coated unfueled partial element specimens. Pyrofoil cemented with C-7 epoxy to graphitite "G" filler strip	5	.10 to .17	On initial motion cycle at approximately 3250°R the coefficient of friction was approximately 0.41
2) 0.003 pyrofoil between the graphitite "G" filler strip and NbC coated unfueled partial element specimens. Pyrofoil cemented with C-7 epoxy to graphitite "G" filler strip	3	.11 to .16	On initial motion cycle at approximately 3000°R the coefficient of friction was approximately 0.38
3) 0.003 pyrofoil between the graphitite "G" filler strip and NbC coated unfueled partial element specimens. Pyrofoil cemented with C-7 epoxy to graphitite "G" filler strip	4	.19 to .34	On initial motion cycle at approximately 3200°R the coefficient of friction was approximately 0.28
4) 0.003 pyrofoil between the graphitite "G" filler strip and NbC coated unfueled partial element specimen. Pyrofoil cemented with C-7 epoxy to NbC coated unfueled partial element	2	.15	On initial motion cycle at approximately 2800°R the coefficient of friction was approximately 0.37
5) 0.005 pyrofoil between the graphitite "G" filler strip and NbC coated unfueled partial element specimens. Pyrofoil cemented with C-7 epoxy to graphitite "G" filler strip	2	.11 to .18	On initial motion cycle at approximately 2800°R the coefficient of friction was approximately 0.35
6) 0.005 treated pyrofoil between the graphitite "G" filler strip and NbC coated unfueled partial element specimens. Pyrofoil cemented with C-7 epoxy to graphitite "G" filler strip	2	.10 to .17	On initial motion cycle at approximately 2800°R the coefficient of friction was approximately 0.37
7) 0.005 pyrofoil between the graphitite "G" filler strip and NbC coated unfueled partial element specimens	5	.13 to .21	On initial motion cycle, no stick slip phenomenon occurred.

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FIGURE 7

FILLER STRIP AFTER TESTING
EML-E.4

FIGURE 8

FILLER TILE - FILLER TILE TEST ASSY.
EML-E.4

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TFL-1. a Single Cluster Development Tests

Work is progressing on the cluster-lateral support test model. This new model will differ from the present test model in several ways. Instead of a normal graphite center element, boron nitride will be employed over the entire length of the element, with the exception of the coated tip, which will be retained in order to maintain the proper interface with the support block. The boron nitride will insulate the tie rod channel from the elements both electrically and thermally. The center element will also be protected from the other elements, over the axial length where element temperatures exceed the allowable limit for boron nitride, by 1/8 inch thick pyrolytic graphite strips on each face of the hexagon. All detail drawings of this model have been completed and hardware procurement is in progress.

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

Design of the water injection high power-high flow test model is in progress. This model will permit the use of higher temperatures in tests.

It is planned to conduct tests using a long hot end chuck. This longer chuck will grip the element farther from the hot end; thus eliminating the question of electric current at the hot end of the element. It is also planned to conduct tests using a nine inch piece of element which will be reversed and placed in the exit end of the furnace. It will be heated directly by the exit gas without any electric current passing through it.

TFL-5. b Interstitial Corrosion Tests

Four tests were conducted this period. The first three tests were conducted to study the corrosion rate of non-thermalized pyrofoil in reactor configurations. The fourth test was conducted to study temperature effects on the corrosion rate of core filler strip material. The first three tests simulated the NRX-A6 wrapper

using a 0.010 inch thick non-thermalized pyrofoil specimen in contact with a 0.280 inch deep by 0.006 inch wide NbC coated filler strip gap. All three tests were operated for a period of 30 minutes at material temperatures of 3497, 3496, and 3499°R respectively. The first two had a flow rate of 4.27×10^{-5} lb/sec-H₂ and the third had a flow rate of 8.58×10^{-5} lb/sec-H₂. In all three tests the corrosion took the same general form. Corrosion was observed on all four edges of the specimen in addition to attack opposite the flow slot, Figures 9, 10, and 11. The weight loss of the third specimen was not significantly higher than the first two despite higher flow rate.

The fourth test was conducted on a standard 0.006 inch thick, 1.00 inch wide flow slot. The test was operated for a period of 15 minutes with an average material temperature of 2905°R and a pressure level of 200 psig. The corrosion rate was 1.89×10^{-5} gms/in²-sec. This was significantly lower than the 1.15×10^{-4} gms/in²-sec obtained at the 3500°R temperature level in a previous test. It is planned to conduct more tests to investigate other temperature levels.

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Test No.	TFL-5.b-033	Inlet Mtl. Temp (°R)	3476
Specimen Ser. No.	73	Outlet Mtl. Temp (°R)	3518
Test Time (Min)	30	Average Mtl. Temp (°R)	3497 Ave.
Inlet Pressure (psig)	350	Flow Rate (lb/sec H ₂)	4.27 x 10 ⁻⁵
Inlet Gas Temp (°R)	526	Graphite specimen wt. loss (gms)	.080
Outlet Gas Temp (°R)	1951	Pyrofoil specimen weight loss (gms)	.061

FIGURE 9
FILLER STRIP PYROFOIL CORROSION SPECIMENS

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Test No.	TFL-5.b-035	Inlet Mtl. Temp (°R)	3484
Specimen Ser. No.	77	Outlet Mtl. Temp (°R)	3508
Test Time (Min)	30	Average Mtl. Temp (°R)	3496 Ave.
Inlet Pressure (psig)	350	Flow Rate (lb/sec H ₂)	4.27×10^{-5}
Inlet Gas Temp (°R)	520	Graphite specimen wt. loss (gms)	.136
Outlet Gas Temp (°R)	NG	Pyrofoil specimen weight loss (gms)	.078

FIGURE 10
FILLER STRIP PYROFOIL CORROSION SPECIMENS

Test No.	TFL-5.b-036	Inlet Mtl. Temp (°R)	3465
Specimen Ser. No.	70	Outlet Mtl. Temp (°R)	3534
Test Time (Min)	30	Average Mtl. Temp (°R)	3499 Ave.
Inlet Pressure (psig)	350	Flow Rate (lb/sec H ₂)	8.58 x 10 ⁻⁵
Inlet Gas Temp (°R)	518	Graphite specimen wt. loss (gms)	.110
Outlet Gas Temp (°R)	2460 +	Pyrofoil specimen weight loss (gms)	.082

FIGURE 11
 FILLER STRIP PYROFOIL CORROSION SPECIMENS

EML-A.1 Reactor Assembly Fastener Static Load Test

A static load test of an NRX A6 reactor assembly fastener, that is being considered for use in the split-type insulating cylinder design, was made.

This test was performed by mounting the test specimen, which consisted of three fasteners assembled with a representative section of the insulating cylinder, in a standard testing machine, and applying a tensile load. Load-deflection data was simultaneously recorded.

The test results determined that a linear ratio between the load and deflection of 126000 lb/inch exists to 1500 lb. Significant increase in the deflection rate occurred for loads to 3200 lb where a total deflection of 0.075 inch was obtained. These results compare favorably with tests previously performed on single fasteners. Figures 12 and 13 show the test specimen before and after the tensile test.

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FIGURE 13 FASTENER TEST SPECIMEN-AFTER TEST
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FIGURE 12 FASTENER TEST SPECIMEN-BEFORE TEST
EML-A.1

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EML-B.1 Fuel Element Permeability Tests at Temperature

Permeability tests were conducted on two elements as a part of a joint fuel material development program with the Materials Department. While it is the intent of the program to include the effects of new flour combinations as well as impregnated and pyro-coated elements, all of the tests to date have been on elements made with type w flour and GA beads.

The first element tested was a WANL Code 9, S/N 33868. It was first tested in He with mean pressures ($\bar{P}$) varying from 25 to 55 psia, pressure differences (ΔP) of 10 to 70 psid and temperature (T) from room temperature to 4500°R. The test was then rerun with hydrogen under the test conditions described above. Figure 14 is a plot of the leakage flow as a function of temperature for the helium test. Figure 15 is a plot of leakage flow for the hydrogen test.

The second element tested, Code 9 S/N 31330, included a molybdenum overcoat with an NbC coating 1-1/2 to 2 mil thick at Station 20. This element was run over the same parameter ranges as the first one but with H₂. Figure 16 shows the variation of leakage per unit length with temperature and pressure.

FIGURE 14
 EML-B.1

FIGURE 15
 EML-B.1

FIGURE 16
EML-B.1

EML-E.1 Core Periphery Testing

Several investigations on the core periphery were completed in the past month. They were primarily directed at development of a wrapper which will withstand temperature and pressure conditions with large filler strip gaps.

a. Room Temperature Testing of Pyrofoil Wrapper Material

A part of the evaluation of the pyrofoil core wrapper is an investigation of the ability of the foil to bridge various gaps. During the last report period, while high temperature tests were being conducted in the core periphery rig at relatively low pressure differentials a full range of pressure differences across a 300 mil gap was being studied at room temperature. The test required was one which could quickly show that pressure differentials across six layers of five mil foil of over 50 psid were not impossible. This was accomplished through the use of two aluminum plates sandwiched between the flanges of an existing pressure vessel. The plates are shown in Figure 17 with the foil contacting surfaces exposed. Figure 18 shows a foil pack installed over the 300 mil gap. The rectangular picture frame is the high pressure side and the 300 mil slot is the low pressure side.

Radial sealing between the two test rings was accomplished by bolting pressure on, and deformation of the pyrofoil outside the 4 x 6 rectangular picture frame on the thickest flange. This led to the problem which produced the erratic results shown in Table IV. (The test numbers in Table IV correspond to the pack numbers in Figure 19). As can be seen from the Table and from Figure 19, the foil packs ruptured at pressure differences low as 30 psid and held at pressure differences as high as 100 psid. The object of the test was to prove this latter point and it is, therefore, considered successful.

The problem of the erratic results and low pressure ruptures can be attributed to air which is trapped between the foil layers when the edges are sealed outside the 4 x 6 rectangular frame. This allows the pressure to be transmitted to each foil independently up to the point where all the trapped

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FIGURE 17

View of Plates Used for Testing Pyrofoil
Under Pressure. The Slot is 300 Mils Wide.
EML-E.1

FIGURE 18

View of Pyrofoil Test Specimen. Note
the Depression of Foil into the Slot.
EML-E.1

FIGURE 19
TEST SPECIMENS USED FOR PRESSURE TEST. THE NUMBERS
CORRESPOND TO TABLE IV
EML-E.1

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TABLE IV

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<u>Test Number</u>	<u>Differential Pressure (Psi)</u>	<u>Cycles</u>	<u>Remarks</u>
1	25	1	Failure. Degassed foil*
2	25	1	Failure. Degassed foil*
3	25	1	Rupture in first layer only
4	85	1	No failure
5	95	1	Failed
6	70	1	Failed
7	100	2	No failure
8	100	3	Failed shortly after application of press.
9	30	1	Five min. duration. First layer ruptured
10	30	6	Rupture in first layer only
11	40	6	Rupture in first layer only
12	50	1	Failed at start of second cycle
13	35	1	Failed
14	50	6	No failure; five minute cycle
15	60	6	First layer failed
16	70	1	Failed at 55 psi second cycle
17	70	6	No failures
18	80	1	Failed at 40 psi second cycle
19	80	6	First layer failed
20	90	1	Failed at 40 psi beginning of 2nd cycle
21			Not run
22	90	1	Failed at 65 psi second cycle
23	16	1	1 layer 0.005 foil failed
24	16	1	1 layer 0.005 foil failed
25	20	1	2 layers 0.005 foil failed
26	17	1	2 layers 0.005 foil failed
27	21	1	1 layer 0.010 foil failed
28	23	1	1 layer 0.010 foil failed

*All tests on green foil except as noted.

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air can be enclosed in the deformation into the gap. This effect is negligible in the high temperature core periphery rig because of the different loading mechanism. Attempts to modify assembly techniques to avoid the problem in the room temperature rig were unsuccessful. It has, therefore, been concluded that more meaningful results for room temperature tests will be achieved only through a loading mechanism similar to that in the core periphery rig.

b. Elevated Temperature Core Periphery Tests

The objective of six thermal and pneumatic cycles on the core periphery was achieved during the last report period. The periphery tested was Build 4. This consisted of:

- a. A5 filler strips (coated),
- b. Grooves of 100, 150, 200 and 300 mils cut in four filler strips to simulate the effects of varying degrees of filler strip corrosion,
- c. Five staggered layers of five mil pyrofoil plus a sixth fullwidth wrapper, and
- d. Communication holes to vent the filler strip gaps to the low pressure side of the periphery.

The results of this test showed that: 1) the foil can withstand over 25 psi pressure difference while bridging gaps up to 300 mils at temperatures to 3500°R; 2) the foil is not damaged by core motion during core heatup, cool-down and bundling for six cycles; 3) the results for multiple cycles are not noticeably different from single cycle tests. A slight increase in foil embrittlement was noticed but this is attributed to integrated time at temperature rather than the cyclic nature of the test.

Photographs showing the results are as follows. Figure 20 shows the hot, low pressure side of the periphery and the low pressure side of the communication holes. Figure 21 shows the bottom view of the core; note the small depression of the foil into the gaps. Figure 22 shows the top view of the core. Note that the foil has protruded into the gaps to a greater extent.

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FIGURE 20

FIGURE 21

FIGURE 22

FIGURE 23

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The degree of the break in the first layer of foil in the 300 mil gap is exaggerated by a deposit. The break is only about 1/4 inch long. The effect observed is not unlike that which caused the erratic results in the room temperature tests. Compare these latter two photographs with Figure 23 from Test No. 1. The depressions are quite similar. Figure 23 shows the results for a single cycle test on the same build and temperature, but for a short pressure differential application. It also illustrates the change in container design which has resulted in:

- 1) the capability for 40 psid pressure difference testing and
- 2) a cost saving in manufacturing. The dark colored substance on the containers is thermal insulation which is being used in an attempt to alleviate the thermal stress problems in the container.

Figure 24 shows the first layer of foil and the pyrotiles from Build 4. The three 1/8 inch diameter holes are for the thermocouples which measure filler strip temperature. The black markings are soft soot which is deposited in areas where there is flow leakage.

c. Elevated Temperature Testing of the Core Periphery at Design Bundling Pressure

After completion of the six cycles reported above, the rig was disassembled, inspected and photographed. It was then reassembled with new foil and tested for two more cycles at 3500°R and pressure differentials of 40 psid. At the end of the second cycle the container experienced a thermal stress failure. The rig was then disassembled and photographed. Figure 25 shows the top end of the core. In this instance the whole foil pack has deformed locally into the 300 mil gap as opposed to the normal deformation of the single innermost foil. There is also a 1/4 inch long break. The deformation was almost negligible on the bottom of the core. From this evidence it is concluded that the damage and separation of the foils at the top is caused primarily by the movement of the top loading block.

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FIGURE 24
FIRST LAYER OF FOIL
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FIGURE 25
TOP VIEW OF CORE
EML-E.1

d. Thermal Gradient Studies in Graphitite "G" Cylinders

During the report period two more thermal gradient studies were completed. These are being performed on 1-1/2 inch diameter cylinders which were heated on their outside diameters in the 6 x 10 furnace and cooled on their inside diameters with a 3/8 inch O.D. tube. Five thermocouples on three different radii provide the temperature readings necessary to allow analysis of the temperature gradients. The simple geometry makes accurate computation of the gradients and their attendant stresses possible. Figure 26 shows one of the samples with the thermocouples installed. Data reduction is not complete but preliminary investigations have shown that a 1500°R gradient results in a crack, Figure 27; while a 1100°R gradient results in no cracking. This has led to the conclusion that Graphitite "G" is indeed susceptible to thermal stress cracking and substantiates data currently used by Stress Analysis.

EML-E.3 Aft End Impedance Tests

Aft end impedance sleeves have been bonded to the elements of the model 9-1/2 inch x 7 inch cluster core; Figure 28 shows the core assembled in the pressure vessel. The overall test setup is depicted in Figure 29. The initial data from the tests is shown in Figure 30; and indicates a significant reduction in interelement flow when compared with standard-tolerance sized elements.

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FIGURE 26
GRAPHITITE "G" CYLINDER
EML-E.1

FIGURE 27
SECTIONED SPECIMEN AFTER TESTING
TO A GRADIENT OF 1500°R . NOTE
THE RADIAL CRACK.

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FIGURE 28
FLOW IMPEDANCE TEST
EML-E.3

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FIGURE 29
FLOW IMPEDANCE TEST RIG WITH SEAL
EML-E.3

FIGURE 30
FLOW IMPEDANCE TEST SETUP
EML-E.3

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Thermo-Flow Laboratory

The DAS trailer now located at WANHES has been completely equipped. The data handling racks and equipment have been installed and are ready for wiring. It is planned to move the trailer to WANL to complete the wiring.

Engineering Mechanics Laboratory

Thermal Gradient Facility

A checkout run was conducted on the thermal gradient facility. The cryogenic pump was in operation for sixty-nine minutes and power was applied to the heaters for about thirty minutes during the run. An apparent heater malfunction resulted in test termination before cryogenic gas flow or heater power could be adjusted to give the desired core-reflector interface temperature conditions. Based on the facility performance during this checkout run, indications are that much meaningful test data should be generated during future tests.

Disassembly of the test specimens and data reduction are currently in progress.

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