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October 16, 1967

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Westinghouse Astronuclear Laboratory

NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW MEETING
HELD WITH SNPO AT WANL ON OCTOBER 3, 1967
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NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW MEETING
HELD WITH SNPO AT WANL ON OCTOBER 3, 1967
(Title Unclassified)

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

E. A. DeZubay, Manager
Thermo-Flow Laboratory

~~INFORMATION CATEGORY~~

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~~ 11/6/67~~
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~~Excluded From Automatic Downgrading
and Declassification~~

C. L. Meuche, Manager
Engineering Mechanics Laboratory

SPECIAL REREVIEW FINAL DETERMINATION	Class.	Date
	DBW U 4-27-82	
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NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW
MEETING HELD WITH SNPO AT WANL ON OCTOBER 3, 1967

ATTENDEES:

E. A. DeZubay	WANL	H. D. Murphy	SNPO-C
R. N. Eichbauer	WANL	R. Muth	WANL
N. J. Ettenson	WANL	J. S. Olinger	WANL
H. J. Fix	WANL	M. J. Rieb	AGC
W. J. Havener	WANL	W. J. Rowan	WANL
G. A. Kalvin, Jr.	SNPO-C	L. A. Salvador	WANL
I. Kanter	WANL	F. G. Tauch	WANL
C. L. Meuche	WANL	D. C. Thompson	WANL
D. F. Miller	WANL	E. Watjen	WANL
		E. S. Ziurys	SNPO-C

The Monthly Development Test Program Review Meeting was held on
October 3, 1967.

This report is divided into two discrete sections. The first section covers
the activities of the Thermo-Flow Laboratory and the second, those of the
Engineering Mechanics Laboratory. Table I of each section lists the tests performed
during the reporting period and those planned for the next period. Discussions of
the individual tests follow.

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SECTION A

MONTHLY REVIEW OF THERMO-FLOW EXPERIMENTS

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TABLE 1
THERMO-FLOW LABORATORY TEST SCHEDULE

PERFORMED THIS PERIOD (September)

PLANNED NEXT PERIOD (October)

Tests for NRX-A6

TFL-1. a Single Cluster Tests - WANL-TME-1665 summarizing
NRX-A6 proof tests was published.

No activity.

TFL-1. b Element Pressure Tests - designed and fabricated
test rig.

Conduct tests.

TFL-2. a Filler Strip Model - TFL-2. a. 0003 tested.

Complete disassembly and inspection.
Reduce and analyze data.

TFL-6. c R. R. Car Reactor Purge - conducted tests.

No activity.

Tests for NR-1

TFL-1. a Cluster Tests.

Procure hardware for NR pedestal develop-
ment tests.

TFL-1. d Orifice Calibration and Test - initiated testing.

Continue testing.

TFL-2. a Filler Strip Model - design layout for NR test
partially complete.

Continue NR model design.

General Development

TFL-1. b Single Element Tests - total tests, twenty-six (26).

12 - High void - 11 Phase I-D

1 Phase II-A-2a

1 - NRX-A6 O. D. element

3 - Phase I-E (A-6 elements at NR conditions)

1 - Furnace development

9 - Hot end chuck development tests

Tests of high void elements from Phase I-D,
(LTRM coatings of high void elements).
Phase I-E tests, (A-6 elements at NR
conditions).

Continuation of hot end chuck develop-
mental testing.

TFL-5. b Interstitial Corrosion - conducted two tests.

Continue testing.

TFL-5. d Reactor Graphite Hot End Impedance - conducted
swelling tests.

Continue testing.

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TESTS FOR NRX-A6

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TFL-1. a Single Cluster Development Tests

(U) WANL-TME-1665, which summarizes all of the NRX-A6 proof tests, was published during this period. This completes the NRX-A6 testing in this area.

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

(U) A new test model, which will be used for element pressure tests, has been designed and fabricated during the period. It is planned to test fuel element sections for physical damage through sudden pressure drop. The test will be conducted by subjecting the test section to a pressure of 750 psi and then dropping the pressure 400 psi per second. Three 8-inch sections from each element will be tested in this manner. At the present time it is planned to use two elements from WNCO and two from Y-12. All four elements will be Code 21 fueled.

TFL-2. a Filler Strip Corrosion Tests

(C-RD) Test TFL-2. a. 0003 was conducted with the filler strip test model, which was previously described in WANL-TME-1645. The test was conducted using hot hydrogen and operated for a period of 69.2 minutes at full power. The test operated with an average ΔP of 15 lbs, a flow of 0.012 lbs/sec, and power of 105 KW. The 36-inch thermocouple went out after 12 minutes of operation making it necessary to switch over to the 26-inch thermocouple for the balance of the test. Figure 1 is the thermocouple output record for both the station 26 and 36-inch in-core thermocouples. The 4000°R recorded for the 26-inch station corresponds to a temperature of 3700°R on the outer layer of the grafoil wrapper at station 36.

(C-RD) Figure 2 shows the condition of the tile after the test. There is considerable corrosion near the aft end of the tile. The grafoil from the fifth layer into the core appears to be intact with the exception of several small, localized perforations. Figure 3 shows the fifth layer of grafoil. The outer four layers of grafoil were corroded through in the areas of the gaps between insulating tiles.

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- IN-CORE STATION 26 THERMOCOUPLE
- △ IN-CORE STATION 36 THERMOCOUPLE
- X THERMOCOUPLE FAILURE

FIGURE 1

TEMPERATURE TIME HISTORY OF TEST TFL-2. a. 0003

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FIGURE 2

INSULATING TILES AFTER TEST TFL-2. a. 0003

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FIGURE 3

GRAFOIL WRAPPER (LAYER 5 OF 9)
FROM TEST TFL-2, a. 0003

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(C-RD) This corrosion was evident over the last 2/3 of the core. Figure 4 illustrates the condition of the outer layer of grafoil. Disassembly and inspection of the model is continuing and the data is being reduced and analyzed.

TFL-6. c Railroad Car Reactor Purge System

(U) A test was conducted on the NRX-A6 shipping container purge system which is mounted on the railroad car. The test was conducted to determine the pressure drop in the system for a nominal air flow of 1.5 SCFM. The pressure drop on the inlet flow system was determined to be 12 psid and the drop on the outlet flow system was 2.1 psid.

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FIGURE 4

GRAFOIL WRAPPER OUTSIDE LAYER (LAYER 9)
FROM TEST TFL-2. a. 0003

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TESTS FOR NR-1

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TFL-1.a Single Cluster Development Tests

(U) Procurement of hardware for the NR pedestal development tests has been initiated. Reactor parts for the NR cluster tests have been ordered and delivery is estimated to be in late October.

TFL-1.d Orifice Calibration and Test

(C-RD) A test has been initiated to determine the loss coefficient for ten orifices, of throat diameters ranging from 25.5 to 70 mils, which may be used in high void fuel elements. These fuel elements have channel diameters of approximately 107 mils. Calculations show that the loss coefficient of these orifices may differ from those calibrated in a 94 mil channel. The test will be conducted on 10 orifices of nearly the same throat diameter as their NRX-A6 master counterpart. The loss coefficient of these orifices will be determined at ambient temperature and 705 psia for channels of 94 and 107 mils in diameter. To date, fifteen tests have been conducted with the 94 mil channel. A total of 40 tests will be conducted for this program. The 107 mil channel test model is being fabricated.

TFL-2.a Filler Strip Corrosion Tests

(U) The design layout for the NR tests is partially complete. Work is continuing in this area on schedule.

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GENERAL DEVELOPMENT TESTS

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

(C-RD) There were 26 single element tests conducted at WANL during the period. Of the 26 elements tested, eleven were high void type from Phase I-D (LTRM coated), and one element was from Phase II-A-2a. These element tests operated for varying times of from 5 to 60 minutes. Hot end failures and pin holing caused the tests to be shut down. There was one NRX-A6 O.D. coated element tested in order to measure the internal web temperature at the hot end of the element. Three NRX-A6 elements were tested at NR conditions, Phase I-E, one of them being successfully tested for the full 60 minutes. There was one element tested for furnace development and nine elements tested for hot end chuck development.

(C-RD) The hot end chucks are being modified to better simulate the NR axial temperature profile. Figure 5 shows the desired profile and also the profiles obtained with the various chuck modifications. Figures 6, 7, and 8 show the cross sections of the chucks listed on the table of Figure 5.

(C-RD) It is planned to conduct tests of high void elements from Phase I-D (LTRM coatings of high void elements), and elements from Phase I-E. There will also be a continuation of hot end chuck development tests.

(C-RD) Single fuel element tests at WANHES have routinely been testing fuel development elements for both WNCO and Y-12. In addition to these tests, the characterization test plan for NRX-A6 has been initiated. This characterization is a statistical test plan to determine the behavior of NRX-A6 for power, flow, and cyclic influence. The plan consists of four parts, three elements for the determination of life (time to failure at the worst possible conditions), part one of 64 elements to determine parametric effects, part two of 48 elements linked to part one to expand material and coating effects, and a secondary side plan of eight elements at materially reduced power and flows. To date the following degree of completion has been made: three pretest elements have been tested,

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FIGURE 5
ACTUAL TEMPERATURE DISTRIBUTIONS
FOR VARIOUS CHUCK CONFIGURATIONS

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FIGURE 6
43 INCH DOUBLE CONTACT CHUCK

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FIGURE 7
45.5 INCH DOUBLE CONTACT CHUCK

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FIGURE 8

45.5 INCH DOUBLE PARALLEL PATH CHUCK

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twelve of the 64 elements of the first part have been tested, and the side plan has been completed. It is planned to follow this test plan through to completion simultaneously with routine process development and reactor qualification tests.

(C-RD) The across flats dimensions of fuel elements and hot end chucks were measured to determine the type of fit normally obtained. Figure 9 is a plot of this information and indicates the maximum and minimum limits. Only one element measured had any sign of arcing between the element and chuck and it falls outside the normal pattern. When sufficient data is obtained it may be possible to measure only the fuel element, and determine the corresponding chuck size. This procedure would eliminate the possible variance in fit attributable to the skill of the technician.

(U) The data on the relation between the hot end dimensions of peripherally coated NRX-A6 elements and their performance in the electrical corrosion test was presented.

(C-RD) Table 2 indicates relative performance of two groups of elements. Group I had variations in across flats dimensions of 0.0007 inches or less while Group II variations exceeded 0.0007 inches.

TABLE 2

	Completed 30+30 Min.	Did Not Complete 30+30 Min.	Total
(C-RD) Group I (0.0007 Inch or Less Variation)	31	38	69
(C-RD) Group II (Greater Than 0.0007 Inch Variation)	12	6	18
Total	43	44	87

(C-RD) A statistical analysis of the data in Table 2 indicates no significant relation between across flats variation and completed tests.

FIGURE 9

CORRELATION OF CHUCK AND FUEL ELEMENT DIMENSIONS

(C-RD) The data in Table 3 indicates relative performance of two groups of elements separated on the basis of tip dimensions. Group A are elements with across flats tip dimensions 0.0005-inch or more, greater than dimensions at 7/8-inch from the end, while Group B had across flats tip dimensions 0.0005-inches or more, less than dimensions at 7/8-inch from the end.

TABLE 3

	Completed 30+30 Min.	Did Not Complete 30+30 Min.	Total
Group A (Bulbous tips)	7	6	13
(C-RD) Group B (Tapered tips)	13	15	28
Total	20	21	41

(C-RD) A statistical analysis of the data in Table 3 also showed no relation between element dimensions and performance in the electrical test.

TFL-5. b Interstitial Corrosion Tests

(C-RD) Two tests studying the corrosion characteristics of an advanced reactor composite material and a hexagon impedance sleeve were conducted during this report period.

(C-RD) The first configuration consisted of an NbC coated stack of four various size cylinders fabricated from composite material and brazed together. Figure 10 shows the specimen with molybdenum supports used to hold it in the molybdenum hardware. The purpose of the test was to evaluate corrosion in a 0.005-inch wide scratch on the surface of one of the cylinders which penetrated the NbC coating. Figure 11 shows the scratch before test. The specimen was tested at the following conditions with the following results:

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INLET

COMPOSITE MATERIAL TEST FIXTURE

Ser. No. SD4-4-5

FIGURE 10

COMPOSITE SPECIMEN AND SUPPORTS BEFORE TEST

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FIGURE 11

SCRATCH ON COMPOSITE SPECIMEN BEFORE TEST

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(C-RD)

Test Number	TFL-5. b. 048
Test Time (min)	60
Inlet Pressure (psig)	350
Inlet Gas Temperature ($^{\circ}$ R)	535
Average Material Temperature	3520
Flow Rate (lb/sec- H_2)	8.64×10^{-5}
Initial Weight (gms)	39.173
Weight Loss (gms)	0.314

Post test microscopic measurement showed that the scratch on the specimen had expanded in width to a maximum of 0.0057-inches. Other dimensions of diameters and height showed no significant change. Even under high power, it was difficult to establish the extent of corrosion damage due to the composite matrix of the material.

(U)

The bottom portion of the specimen had some chips which appeared to have been caused by rough edges on the exit molybdenum holder. These chips were responsible for a large percentage of the total weight loss. Figure 12 shows the general configuration after test. Figure 13 shows the post test scratch condition.

(C-RD)

The second configuration consisted of a hex impedance sleeve fixture. The fixture consists of a standard hex wrapped with 0.0055-inch thick reactor grade "Grafoil". This item is contained in a cup with a matching internal hexagon. Figure 14 shows the general specimen configuration. Figure 15 is the assembled hardware lighted from the bottom showing what areas are open to flow and the general order of magnitude of the gaps. The fixture was tested at the following conditions with the following results:

Test Number	TFL-5. b. 049
Test Time (min)	30
Inlet Pressure (psig)	350
Inlet Gas Temperature ($^{\circ}$ R)	3708

FIGURE 12
COMPOSITE SPECIMEN AND SUPPORTS AFTER TEST

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FIGURE 13

SCRATCH ON COMPOSITE SPECIMEN AFTER TEST

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FIGURE 14
GENERAL CONFIGURATION OF
IMPEDANCE SLEEVE SPECIMEN BEFORE TEST

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FIGURE 15
ASSEMBLED IMPEDANCE SLEEVE SPECIMEN
LIGHTED FROM THE BOTTOM

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	Average Material Temperature ($^{\circ}\text{R}$)	3708
	Flow Rate (lb/sec- H_2)	3.03×10^{-6}
	Pre Test Hexagon Weight (gms)	27.086
(C-RD)	Pre Test Cup (gms)	59.345
	Hexagon Weight Loss (gms)	0.057
	Cup Weight Loss (gms)	0.574

Upon disassembly, corrosion was present on the corners of the "Grafoil" hexagon sleeve for most of its 1.00-inch length. Corrosion was also present on the flats that were open to flow as shown on Figure 15. This damage extended about 0.250-inches along the flat. No severe damage to the scarf joint was noticed. Figure 16 shows the general condition after test. Removal of the NbC coating on the O.D. of the cup was necessary to fit it in the holder. Figure 17 shows a close-up of the "Grafoil" sleeve. Figure 18 shows the assembled fixture after test describing the changes in the flow paths created by swelling of the "Grafoil" sleeve.

(U) The 12-inch pressure vessel was hydrostatically tested to 1500 psig. A parallel effort is in progress to prepare the loop, cell, and control console prior to the furnace delivery.

TFL-5. c Reactor Graphite Component Permeability Tests

(C-RD) A grafoil swelling test was conducted at 350 psig in the 18-inch furnace using helium. The test specimen consisted of a grafoil wrapped hexagon situated inside a NbC coated hexagon holder. The hexagon gap was measured to be approximately 0.001-inch. Mass flow rates were measured for pressure drops from 20 to 600 in H_2O from 535 to 3750 $^{\circ}\text{R}$. The results showed that swelling ceases at 3300 $^{\circ}\text{R}$.

(U) A hydrogen corrosion test was attempted on a similar test specimen. The specimen temperature attained was only 3080 to 3120 $^{\circ}\text{R}$ because of arcing. The

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FIGURE 16
GENERAL CONDITION OF IMPEDANCE SLEEVE FIXTURE AFTER TEST

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FIGURE 17
CONDITION OF "GRAFOIL" SLEEVE AFTER TEST

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FIGURE 18

PATHS OPEN TO FLOW AFTER TEST

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test lasted one-half hour, but the corrosion could not be accurately measured because of the low temperature. This was the first hydrogen run conducted in the 18-inch furnace.

An additional grafoil swelling test is planned for the next period.

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SECTION B
ENGINEERING MECHANICS TESTS

TABLE I
ENGINEERING MECHANICS TEST SCHEDULE

Performed This Period		Planned Next Period	
Tests for NRX-A6			
EML-B.3	Exit Gas Thermocouple Vibration Test		
EML-B.3	Shipping Test of NRX-A6 Cluster	EML-B.3	A6 Shipping Environment Test
EML-E.1	Thermal Shock Test of Pyrofoil		
EML-E.2	Friction Tests of Candidate Foil Attachment Material		
EML-E.4	Ultimate Axial Load Capability of NRX-A6 Fuel Element Brazed Keys	EML-E.4	Support Block Aft End Support
Tests for XE-1			
EML-E.5	XE-1 Control Drum Bearing Test		
EML-B.2	XE-1 Fuel Element Purge Test		
		EML-H.3	XE-1 Debris Removal Tests
Tests for NR-1			
EML-A.4	Fatigue Tests on Bands	EML-A.4	Fatigue Tests on Bands
EML-E.4	Core Wrapper Development	EML-E.4	Core Wrapper Axial Impedance Test
		EML-C.1	Begin NR-1 Pedestal Development
		EML-D.5	NR Angle Seal Development
General Development			
EML-C.1	Support Block Gradient Test	EML-A.2	Beryllium Reflector Properties
		EML-C.1	Unsymmetrical Thermal Gradient Tests on Regular Support Blocks
Facilities			
EML-H.1	XECF Resonant Survey	EML-H.1	XECF Resonant Survey

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NRX-A6

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EML-B.3 Exit Gas Thermocouple Vibration Test

The second phase of testing of an NRX-A6 recrystallized exit gas thermocouple was conducted with the vibratory loads applied in the direction perpendicular to the axes of the tie rod and the thermocouple. A series of sweeps from 15 to 5000 cps and a series of dwells at input acceleration levels of 1 to 30 g's were run on the test setup as shown in Figure 1.

Table II is a summary of the resonances and the time at each acceleration level. Also shown are the damping constants at the 5 and 10 g levels.

The continuity and the resistance to ground was checked before and after the test and these checks indicated that no damage had occurred to the thermocouple.

EML-B.3 Shipping Test of NRX-A6 Cluster

Tests to simulate the assembly leak checks and gas sampling procedures used during shipment of the reactor to the Test Site were initiated. Three fueled clusters were placed in separate aluminum containers. The first container was suspended with elastic rope and was driven by an eccentric lever mounted on the shaft of an electric motor. The arrangement is shown in Figure 2. The container was subjected to sinusoidal motions of 0.4 g at 2 cps for 86 hours and 0.35 g at 4 cps for 12 hours. These levels represent those normally encountered during shipping. While the first container was

FIGURE 1
TEST SETUP PHASE II
EML-B.3

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TABLE II
DYNAMIC CHARACTERISTICS OF EXIT GAS THERMOCOUPLE
EML-B.3

Acceleration Level	Resonance Frequency	Strain At Resonance (ϵ)	Damping Constant*	Time At Level
g	cps	Microinches per inch		
1	1914	26		30 Sec.
2	1913	34		30 Sec.
3	1913	42		30 Sec.
4	1920	51		30 Sec.
5	1913	74	.0653	10 Min.
10	1914	135	.1034	60 Min.
20	1979	370		10 Min.
30	2035	370		30 Sec.

$$* \text{ Damping Constant} = \frac{f_2 - f_1}{f_R}$$

f_R = Resonance Frequency

f_2 = Frequency greater than f_R where strain is 70% of ϵ

f_1 = Frequency less than f_R where strain is 70% of ϵ

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FIGURE 2
ARRANGEMENT FOR CLUSTER SHIPPING TEST
EML-B.3

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being tested, a test rig was fabricated to drive all three containers simultaneously. It was anticipated that approximately midway through the first test, the three units would be assembled into the new test rig thereby allowing the tests to be completed in parallel rather than in series. A trial run revealed a bearing problem with two of the three units installed, the approach was discarded and the first test was continued until completion. The systems were then built for individual tests in a manner similar to the first setup.

The major variation between the planned tests were the gaseous environment employed. In Test 1 bottled breathing air in the container was changed every 12 hours; in Test 2 the cluster would be enveloped in helium gas at 6 psig and in Test 3 the cluster/container would be continually purged with breathing air.*

Preliminary information from Reactor Assembly reports no visual debris seen upon the first container.

EML-E.1

Thermal Shock Test of Pyrofoil

The periphery wrapper and slip plane of the A-6 and subsequent reactors are formed from PDS 30182-2 (non-degassed) Grafoil strips using petrolatum as an assembly aid. To determine whether outgassing of the foil and vaporization of the petrolatum during reactor heat-up rates will cause catastrophic bubbling and/or cracking in the foil, three tests were conducted in the 6 x 54 inch furnace using thermal shock fixturing developed for NR-1 pedestal tests.

The specimens consisted of 1-1/4 diameter pieces of the PDS 30182-2 grafoil cemented together with petrolatum and sandwiched in a specimen

* NOTE: At the release of this document, the third test was changed to utilize helium.

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(U)

holder under 30 psi. Additional layers were placed on top of the holder in an unloaded condition. The assembly is shown in Figure 3. Thermocouples were placed at the center of the foil sandwich and in the gas stream, to monitor temperature rise rates.

(C-RD)

The thermal shock tests consist of preheating a 60 inch long heat exchanger to 5000°R, then flowing high velocity He at 80 SCFM onto the specimen mounted at the exhaust end. The fixture consists of a 19 hole unfueled element inserted in a graphite tube as a heat exchanger and a graphite sleeve surrounded by a water jacket to hold the specimen. The specimen holder, shown in Figure 3, provided a uniformly distributed 30 psi load on the inner foil pack. The outer foil pack was left unloaded because this was thought to be the most severe condition.

(U)

The first test, which included two foil layers placed inside and two on top of the holder, achieved 3600°R at a minimum rate of 100°R/sec on the inner foils. The second specimen consisted of six layers of foil inside and four foil layers on top. This test achieved a 100°R/sec temperature rise to 3950°R on six inner layers of foil and approximately 3000°R/sec to 4160°R on the top mounted four layers. The curves of these tests are shown on the graph of Figure 4.

(U)

The third test consisted of 10 layers of foil placed inside the holder under no load conditions. This was accomplished by mounting a ring about the outer edge of the foil and clamping it in the holder. A temperature rise of 140°R/sec to 3600°R was achieved in the third and final test.

(U)

No significant bubbling of the foil was observed in any of the tests and at no time did catastrophic bubbling or cracking occur due to outgassing. Figure 5 shows the post-test condition of the foils.

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Hot gas was directed on the top of the specimen and exhausted through the slots in the lower ring.

FIGURE 3
TEST SPECIMEN ASSEMBLY FOR PDS 30182-2
PYROFOIL THERMAL SHOCK TESTS
EML-E.1

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FIGURE 4
THERMAL SHOCK OF PDS 30182-2 (GREEN GRAFOIL)
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The top row of foils was exposed to direct impingement of gas at $3000^{\circ}\text{R}/\text{sec}$ and resulted in nearly complete erosion of the layer on the left. The erosion is believed caused by the force of the blast rather than outgassing due to thermal shock.

FIGURE 5
POST-TEST CONDITION OF PYROFOILS AFTER HOT GAS
THERMAL SHOCK TESTING AT $100^{\circ}\text{R}/\text{SEC}$ to 3950°R
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EML-E.2

Friction Tests of Candidate Foil Attachment Material

Tests of NRX-A6 pyrofoil on pyrofoil were performed in hydrogen at 4150°R temperature and 40 psi contact pressure to determine the friction values for petrolatum and Apiezon "T" when used between the foil interfaces.

Reactor startup core periphery temperatures and element inter face motions were simulated by simultaneously heating and sliding of the test specimens followed alternately by temperature and motion "holds".

The average heating and motion rates were 27°R/sec and .002 inch/sec respectively.

Two tests were conducted under the following simulated startup conditions:

1. Start motion and heat up
2. Hold for approximately 3 minutes at 1950°R
3. Start motion and heat up
4. Hold for approximately 10 seconds at 3750°R
5. Start motion and heat up
6. Hold for approximately 10 minutes at 4150°R
7. Reverse motion and cooldown to ambient

The maximum measured coefficient of friction occurred at approximately 3250°R temperature and was about 0.33 for both specimens.

A repeat test using the petrolatum material was made and the maximum friction recorded was about 0.35. This substantiated the previous results and petrolatum was used in the NRX-A6 reactor.

EML-E.4

Ultimate Axial Load Capability of NRX-A6 Fuel Element Brazed Keys

Static tests have been completed to determine the mode of failure and the maximum axial load that can be applied to brazed keys on

(U) NRX-A6 fuel elements. The failures occurred as cracks in the graphite keys at loads ranging from 284 lbs to 347 lbs with an average at 312 lbs for seven test specimens. A typical failure is shown in Figure 6. The test data is presented in the following table.

TABLE III
Test Data

Specimen	Failure Load (lbs)	Deviation From Average (lbs)	% Deviation
1	306	-6	-1.9
2	347	+35	+10.0
3	320	+8	+2.5
4	327	+15	+4.6
5	314	+2	+0.6
6	284	-28	-9.5
7	285	-27	+4.4
Mean Values	312	+15 -20	+4.4 -7.0

(C-RD) The present testing is a continuation of the program to evaluate the interlocking design of element keys and filler strip keyways for the A6 reactor. This interlocking design was originally intended to serve as a redundant axial support scheme for the filler strips should the primary method of friction support prove insufficient. Comparing the present test data to previously reported data for keyway failure, it is seen that the ultimate strength of the fuel element brazed key exceeds that of the keyway by

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FIGURE 6
TYPICAL FAILURE OF THE NRX-A6 FUEL ELEMENT BRAZED KEY
UNDER AXIAL LOAD (SPECIMEN, LEFT SIDE)
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(C-RD) about 100 lbs and 200 lbs for the thicker and the thinner filler strips, respectively. Since the filler strip keyway ultimate strength is insufficient for backup support, however, this loading interface was eliminated in the A-6 reactor.

(C-RD) A schematic of the test loading condition is shown in Figure 7. The test rig is shown in Figure 8. The fuel element key is loaded against a simulated keyway machined into steel stock. Specimens 1, 2, 3, 5, and 7 were tested with no lateral load and hence, near zero frictional forces in the first test arrangement. Specimens 4 and 6 were tested with a lateral load of 68 lbs applied opposite to the mating keyway. This lateral load condition did not result in any significant change in the failure load as seen in the tabulated test data. This was to be expected since the length of the specimen was inadequate to develop any high frictional restraining force. All test failure loads are, therefore, averaged together.

(C-RD) The present test specimens were cut from coating rejected (Class 2) hardware but the keys and braze joints of all specimens were up to reactor grade. In addition, Specimen 3 was rekeyed due to an initial imperfect brazed joint. All other specimens were keyed once.

(U) The present test results show good agreement with those previously reported for NRX-A5 fuel element brazed keys. In that previous investigation eight specimens exhibited similar key failures at an average load of 317 lbs. With the exception of a shortening in key length from 1.000 in to 0.800 in for the A-6 design the braze joints and graphite keys for the A-5 and A-6 are identical.

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FIGURE 7

SCHEMATIC OF THE TEST LOADING CONDITION TO DETERMINE THE ULTIMATE
AXIAL LOAD CAPABILITY OF THE NRX-A6 FUEL ELEMENT BRAZED KEY
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FIGURE 8
FUEL ELEMENT BRAZED KEY ULTIMATE AXIAL LOAD TEST RIG
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EML-E.5 XE-1 Control Drum Bearing Test

A control drum bearing test was performed to determine the torque required to turn the drum for a condition in which the bearings were contaminated with XE-1 reactor debris.

Base line torque was established by conducting 100 cycles $0-180^{\circ}$ - 0 and 50 cycles $90^{\circ} \pm 5^{\circ}$ on a control drum fitted with new reactor grade bearings. Bearing temperatures were maintained at approximately 200°R during the base line run and the maximum torque recorded was 5 in-lbs. At the conclusion of the above base line test, the control drum assembly was removed from the test stand and a visual examination revealed that the bearings were in the as-received condition. Figure 9 shows the aft end bearing housing and bearing after the base line test.

2.771 grams of XE-1 reactor debris was then sprinkled across the aft end bearing housing. Figure 10 shows the aft end bearing housing after addition of debris. The control drum was then rotated to an aft end down position and the debris that fell off was collected and weighed. This amounted to .9506 grams. Figure 11 shows the aft end bearing housing after rotation to the aft end up position.

Another 1.5004 grams of XE-1 debris was then sprinkled across the aft end bearing housing. Figure 12 shows the aft end bearing housing after addition of this debris. A vacuum pump was then attached to the forward end of the control drum fixture and operated for 3 minutes. This pulled debris into the control drum bearings and annulus area. A filter between the control drum and vacuum pump collected .1160 grams of debris. Figure 13 shows the aft end bearing housing area after drawing debris through the control drum.

The aft end bearing housing area was then vacuumed to remove debris that was lying on accessible surfaces. This debris was also collected on a filter

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FIGURE 9
AFT END BEARING AFTER BASE LINE TEST
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FIGURE 10
AFT END BEARING AFTER DEBRIS ADDITION
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FIGURE 11
AFT END BEARING AFTER
UP-DOWN-UP ROTATION
EML-E.5

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FIGURE 12
AFT END BEARING AFTER
ADDITIONAL DEBRIS ADDITION
EML-E.5

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FIGURE 13
AFT END BEARING AFTER VACUUM
PULL THROUGH OF DEBRIS
EML-E.5

U and the quantity collected was 2.1794 grams. Figure 14 shows the aft end bearing housing after vacuuming off the excess debris.

U The difference between the debris and the total debris sprinkled on the aft end bearing housing area was 1.0254 grams which apparently remained in the control drum bearings and annulus.

U The control drum was then installed in the test stand and 50 cycles 0 - 180° - 0, 150 cycles 0 - 90° - 0 and 10,000 cycles 90° ± 1 were run with the control drum bearings at 200 °R. Maximum control drum torque recorded during the above test was 21.5 in-lbs and there was no sticking or hang up of the control drum.

U At the end of the cycling tests, the control drum was cycled several times from 0 - 180° - 0 and 0 - 90° - 0. Maximum torque was approximately 15 in-lbs during these cycles.

U Examination of the control drum bearings after test (Figure 15), revealed that they were in very good condition with some very slight scoring of the surface of the outer race of the aft end bearing. Figure 16 shows that debris had been carried through the control drum and was deposited on various component surfaces.

U Based on the results of this test, there appears to be no potential problem with the XE-1 control drum bearings.

EML-B.2 XE-1 Fuel Element Purge Test

C-RD Tests of XE-fuel elements were performed to determine particle emission that may occur from pressurization and depressurization cycles. Standard fuel elements were subjected to simulated pressure cycles which duplicated those which were performed during reactor assembly and test site

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FIGURE 14
AFT END BEARING AFTER
VACUUMING ACCESSIBLE DEBRIS
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FIGURE 15
CONTROL DRUM BEARINGS AFTER TEST
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FIGURE 16
DEBRIS DEPOSITED ON FORWARD END
BEARING & HOUSING
EML-E.5

checkout. In addition, hydrolized fuel element sections approximately 8 inches long were subjected to simulated pressure cycles duplicating those which were performed during the test site checkout. In all cases a fuel element or element section was placed in an upright container, pressurized and depressurized and the helium gas used for pressurization exhausted through a 1.2 micron filter.

C-RD

Figure 17 shows the arrangement used for testing the 8 inch specimens. The fixture used for full length elements was the same except the container was of sufficient length to accommodate the full length element. A cup at the bottom of the container collected particles that fell from the element. Tests on element serial number 99-23685 were conducted in accordance with Table IV and the tests on all other elements and sections were conducted in accordance with Table V.

U

A summary of the elements tested and the debris weights collected is given in Table VI. Debris was examined by WANL Materials Department and the conclusion was that it was not typical of the XE-1 debris examined but rather appeared to be typical of the residue remaining after final cut to length operation.

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FIGURE 17
FIXTURE FOR FUEL ELEMENT PURGE TEST
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TABLE IV
TEST PROCEDURE FUEL ELEMENT PURGE

Reactor Assembly Area Pressurization Simulation (pressurize in 10 minutes, relieve pressure in 2 minutes). Use Helium Gas

1. Pressurize to 20 psig
Hold 1/2 hour
Increase pressure to 50 psig
Hold 1/2 hour
Increase pressure to 100 psig
Hold 1 hour
Relieve pressure to 0 psig
Pressurize to 100 psig
Hold 1 hour
Relieve pressure to 0 psig
Inspect
2. Pressurize to 8 psig
Hold 1 hour
Relieve pressure to 0 psig
Inspect

Test Site Pressurization Simulation (pressurize in 5 to 10 minutes, relieve pressure in 1 minute). Use Helium Gas

1. Pressurize to 68 psig
Hold 5 minutes
Reduce pressure to 50 psig
Hold 1/2 hour
Relieve pressure to 0 psig
Inspect
2. Repeat 1 above
3. Pressurize to 50 psig
Hold 1/2 hour
Relieve pressure to 0 psig
Inspect

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TABLE V
TEST PROCEDURE FUEL ELEMENT PURGE

Reactor Assembly Area Pressurization Simulation (pressurize in 10 minutes, relieve pressure in 2 minutes). Use Helium Gas

1. Pressurize to 20 psig
Hold 1/2 hour
Increase pressure to 50 psig
Hold 1/2 hour
Increase pressure to 100 psig
Hold 1 hour
Relieve pressure to 0 psig
Pressurize to 100 psig
Hold 1 hour
Relieve pressure to 0 psig
Inspect
2. Pressurize to 8 psig
Hold 1 hour
Relieve pressure to 0 psig

Test Site Pressurization Simulation (pressurize in 5 to 10 minutes). Use Helium Gas

1. Pressurize to 68 psig
Hold 5 minutes
Reduce pressure to 55 psig in 1.6 minutes
Hold 1/2 hour
Relieve pressure to 20 psig in 4.5 minutes, continue pressure relief to 0 psig with valve setting unchanged. Record time from 20 to 0 psig.
2. Repeat 1 above
3. Pressurize to 55 psig
Hold 1/2 hour
Relieve pressure to 20 psig in 4.5 minutes, continue pressure relief to 0 psig with valve setting unchanged. Record time from 20 to 0 psig.
4. Pressurize to 68 psig
Hold 20 minutes
Relieve pressure to 20 psig in 6 min., continue pressure relief to 0 psig with valve setting unchanged. Record time from 20 psig to 0 psig
Inspect

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TABLE VI

Element Serial No.	Mfg.	Bead Type	Vintage	Weight of Debris in Cup (gms)	
				Reactor Ass'y. Series	Test Site Series
99-23685	WAFF	CP	A-4	.0095	.0003
99-23662	WAFF	CP	A-4	.0011	.0001
99-31180	WAFF	GA	A-6	.0008	.0001
69-29212	WAFF	3M	A-5	.0006	.0004
* 99-23662	WAFF	CP	A-4		.0002
* 99-31180	WAFF	GA	A-6		.0008
* 99-23685	WAFF	CP	A-4		.0006

* Approximately 8 inch lengths of these elements were hydrolyzed and then retested under the Test Site series of Procedure B only.

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NR-1

EML-A.4

Fatigue Test on Bands

(U)

The ganged drum band fatigue fixture was modified by incorporation of new band holder blocks and aircraft cable to prevent slipping and twisting of the bands. Five bands from the second lot of band material were cycled around a titanium drum at $\pm 10^\circ$ at a rate of 20° per second and under 5 different steady loads to check out the modified fixture. A band with an axial load of 350 lbs failed at 11,800 cycles and subsequently, bands failed at 14,691, 120,088, 173,509 cycles at axial loads of 515, 190, 130 lbs, respectively. One band with an axial load of 90 lbs had accumulated 498,200 cycles with no failure when the test was stopped. Two bands failed approximately midway between the holder and the drum and two bands failed near the holder. Visual inspection of the failed bands indicate a rough edge condition which could have contributed to the failures.

(U)

Before actual testing is accomplished, some means of preventing twisting of the bands will be incorporated and the condition of the remaining bands will be determined as well as the alignment of the load cable to assure pure axial load.

EML-E.4

Core Wrapper Development

(C-RD)

A test program is in progress to determine the leakage characteristics of the various axial joint conditions which are being considered for the NR-1 core wrapper. The joint conditions consist of butt joints with 20 mil gaps and lapped joints with 40 mil overlap. The testing is being performed in the apparatus shown in Figure 18. Nine layers of 5.5 mil undegassed pyrofoil are sandwiched between two solid graphite half cylinders and this arrangement is then assembled into a pressure vessel for leakage testing. Helium at room temperature is the working gas and a rubber bladder lining the walls of the vessel applies controlled lateral bundling pressure to the foil layers.

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(C-RD) Helium leakage tests were performed for butt jointed foil with 20 mil gaps and lap jointed foil with a 40 mil overlap and in addition, leakage rates were measured for a core wrapper with no joints under the same test conditions. These latter leakage rates will establish a datum level for all tests. The results of the tests to date are shown in Figure 19 and the test data are presently being analyzed.

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FIGURE 18
CORE WRAPPER AXIAL FLOW IMPEDANCE FIXTURING
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FIGURE 19
EVALUATION OF JOINT CONFIGURATION FOR CORE WRAPPER
EML-E.4

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GENERAL DEVELOPMENT

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EML-C.1

Support Block Gradient Test

A regular, coated ATJ graphite support block was given an unsymmetrical gradient test to investigate crack formations resulting from thermal stress. Approximately one complete lobe and interlock of the block was cooled by a water jacket while the remainder was heated from a radiant furnace element at 5000°R . The maximum temperature of the block was 4120°R , while that nearest the water jacket was 2139°R , giving a total measured gradient of 1981°R . No loading was applied during the test.

Subsequent examination of the block revealed no cracking or damage, except for minor coating cracks. It is planned to section and polish the block to determine whether any internal cracking was caused by the temperature differential. Further testing is planned to combine a normal support loading with a high thermal gradient to determine the effect of combined stresses.

This testing is expected to provide data that can support analysis of thermal stresses under reactor operating conditions.

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FACILITIES

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EML-H.1

XECF Resonant SurveyVibration - Instrument Trailer

The instrumentation and vibration equipment has been designed, constructed and checked out for this test. Figure 20 shows the instrumentation trailer and the internal equipment. The trailer was reported in perfect condition when it arrived at the Nevada Test Site.

Sacramento Meeting

A joint meeting between AGC, NTO and WANL was conducted at Sacramento on 9/18/67. The items discussed included operating procedure, modified shaker support structure and schedule. After review of a report on the maximum stress limits of the shield, it was determined that the shaker support structure shown in Figure 21 will rest on the lower shield as shown in Figure 22. The WANL input to the "NTO Procedure for Vibration Testing of XECF at ETS-1) (NTO-I-0345) was presented and reviewed at the meeting.

FIGURE 20
INTERIOR OF INSTRUMENTATION TRAILER
FROM FRONT TO REAR
EML-H.1

FIGURE 20
INTERIOR OF INSTRUMENTATION TRAILER
FROM REAR TO FRONT
EML-H.1

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FIGURE 21
VIBRATION EXCITER AND SUPPORT STRUCTURE
AS ARRANGED IN DUMMY TEST AT WANL
EML-H.1

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FIGURE 22
ETS-1 TEST STAND FACILITIES
(WITHOUT XECF REACTOR INSTALLED)
EML-H.1