CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

MASTER

Records

W. J. Allen
SNPO-C ✓

RECORD COPY

WANL-TME-1624

May 30, 1967

Westinghouse Astronuclear Laboratory

TFL-1a
CLUSTER CORROSION TEST SUMMARY
NOVEMBER 1966 TO FEBRUARY 1967
(Title Unclassified)

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

JUN 20 1967

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

61
~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
Atomic Energy Act - 1954

MASTER

Astronuclear
Laboratory

WANL-TME-1624

May 30, 1967

~~GROUP 1~~

~~Excluded From Automatic Downgrading
and Declassification~~

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

TFL-1a
CLUSTER CORROSION TEST SUMMARY
NOVEMBER 1966 TO FEBRUARY 1967
(Title Unclassified)

by

B. H. Stahl
L. A. Salvador
Thermo-Flow Laboratory

Classification cancelled (changed to)
by authority of D.O.C.
by H.A.C. TIC, date SEP 10 1973

Approved:

E. A. DeZubay
E. A. DeZubay, Manager
Thermo-Flow Laboratory

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

INFORMATION CATEGORY

~~CONFIDENTIAL RESTRICTED DATA~~

W. J. ... 5/3/67
Authorized Classifier Date

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
Atomic Energy Act - 1954

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

Table of Contents

	<u>Page</u>
Abstract	ii
List of Tables	iii
List of Figures	iv
I Introduction	1
II Test Model Configuration	2
III Reactor Hardware Tests	6
A. Test Configurations	6
B. Summary of Test Results	9
C. XE-1 Component Qualification Tests	15
D. NRX-A6 Component Development Tests	20
IV Summary and Conclusions	51
V Bibliography	53

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

WANL-TME-1624

ABSTRACT

This report reviews progress on the TFL-1.a Cluster Corrosion test from November 1966 to February 1967. The results of 14 high-temperature flow tests are presented. These tests fall into two categories: Developmental tests of NRX-A6 support components and qualification tests of the XE-1 exit gas thermocouple assembly. The three NRX-A6 configurations include an ATJ graphite protection cup, a vapor deposited tungsten protection cup, and a niobium carbide composite protection cup, all with skirtless support blocks.

The XE-1 thermocouple assembly was qualified in a nominal 35 minute test at 4300°R. The NRX-A6 components performed adequately in endurance tests of 60 minutes at 4300°R.

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

List of Tables

Table Number	Title	Page
I	Test Summary	7
II	Reactor Components Employed in Cluster Tests	11
III	Component Identification	12
IV	Test Conditions and Results	13
V	Summary of Cumulative Weight Loss Data	14
VI	Summary of Pre and Post-Test Dimensions of Protection Cups	40

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

List of Figures

Figure Number	Title	Page
1	Cluster Corrosion Test Assembly	3
2	Comparison of Axial Temperature Profiles for TFL-1a Cluster Test and NRX-A5	10
3	Exit Gas Thermocouple Assembly for Test TFL-1a.0005	16
4	Exit Gas Thermocouple Assembly for Test TFL-1a.0004	17
5	Thermocouple Assembly, Liner, Cup, and Tie Rod After Test TFL-1a.0004a	19
6	Thermocouple Assembly, Liner Cup, and Tie Rod After Test TFL-1a.0005b	21
7	Skirtless Block and ATJ Cup After 19.8 Minutes at 4283°R (TFL-1a.0002a)	24
8	Skirtless Block and ATJ Cup After 53.4 Minutes at 4283°R (TFL-1a.0002b)	25
9	Axial Cracking of Skirtless Block From TFL-1a.0002b	26
10	Skirtless Block After 79.1 Minutes at 4283°R Top View (TFL-1a.0002c)	28
11	Skirtless Block and ATJ Cup After 79.1 Minutes at 4283°R (TFL-1a.0002c)	29
12	Skirtless Block, ATJ Cup, and Related Hardware From TFL-1a.0002c	30
13	Skirtless Block and Tungsten Cups After 18.5 Minutes at 4283°R (TFL-1a.0001b)	32
14	50X Cross Section of Flange Area of Tungsten Cups TFL-1a.0001	33
15	50X Cross Section of Wall Area on Small Tungsten Cup TFL-1a.0001	34

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

WANL-TME-1624

List of Figures (Continued)

Figure Number	Title	Page
16	50X Section of Wall Area of Large Tungsten Cup TFL-la.0001	35
17	Skirtless Block and Tungsten Cups After 29.9 Minutes at 4300°R (TFL-la.0007a)	37
18	Skirtless Block and Tungsten Cups After 57.9 Minutes at 4300°R (TFL-la.0007b)	38
19	Key to Photomicrographs of Composite and Tungsten Cups From Tests TFL-la.0006 and TFL-la.0007	41
20	Sectional Views of Tungsten Cups, Support Block and Washer from Test TFL-la.0007	42
21	Sectional Views 2 and 3 of Tungsten Cups From TFL-l.a.0007	43
22	Sectional Views 4,5, and 6 of Tungsten Cups from TFL-la.0007b	44
23	Skirtless Block and Composite Cup After 44.5 Minutes at 4300°R (TFL-la.0006c)	45
24	Skirtless Block, Composite Cup, and Related Hardware After 64.4 Minutes at 4300°R (TFL-la.0006d)	47
25	Sectional Views of Skirtless Block, Composite Cup, and Washer from TFL-la.0006d	48
26	50X Sectional Views 9 & 10 of Composite Cup from TFL-la.0006d	49
27	100X Sectional Views 11, 12 and 13 of Composite Cup from TFL-la.0006d	50

I. INTRODUCTION

This report presents the results of cluster corrosion tests conducted in support of reactor component designs. The tests fall into two categories: developmental tests for NRX-A6 and qualification tests for XE-1. The former are tests which were intended to evaluate the skirtless block and three different protection cup configurations. The latter are tests of the XE-1 exit gas thermocouple assembly.

These tests were conducted during the period from November 1, 1966 to April 1, 1967 in the single cluster corrosion furnace at WANL. The model configuration employed in the tests was essentially the same as that described in TME-1511, the preceeding progress report for this component test program.¹ No additional test development was performed on the test model itself.

The current test program is a series of proof-tests of axial support configurations for NRX-A6. The results of these tests will be published following the completion of the NRX-A6 series.

II TEST MODEL CONFIGURATION

The cluster corrosion test model employed in the tests herein reviewed was essentially the same as that described in detail in TME 1511. Figure 1 is an illustration of this model. Basically it consists of the following subcomponents:

- (a) Regular reactor cluster including fuel and axial support system. The center element is modified to electrically insulate the tie rod and other support components.
- (b) Lateral support sleeves to provide radial support for the fuel.
- (c) Hot end and cold end electrical chucks to deliver and remove electrical current for ohmic heating of the fuel.
- (d) Cold end orificing hardware for controlling hydrogen flow at the fuel inlet.
- (e) Direct gas inlet assembly to bring hydrogen to the orifices while maintaining a protective blanket of helium on the outside surfaces of the cluster and furnace hardware.
- (f) Preload mechanism to provide a known tie rod preload prior to the test. This is necessary to make up for the fact that pressure and frictional loadings in the cluster model are lower than in a typical reactor.

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

Figure 1

Cluster Corrosion Test Assembly

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

The cluster is ohmically heated to provide heat input to the coolant gas flow. The temperature of this gas flow is then measured at a point about 4 inches downstream from the support block. The temperature measured at this point is a mixed mean between fuel element channel flow and tie rod coolant flow. Power input to the cluster is controlled on the basis of this exit gas temperature.

In addition to the exit gas thermocouple, other temperature instrumentation is used to gather data for controlling the test and for analysis of the environment in the model following the test. Element surface temperatures are measured by optical pyrometer at four axial stations on the "B" fuel element. Support block surface temperature is also monitored by pyrometer. Exit gas temperature in the tie rod channel is measured by a chromel-alumel thermocouple which spirals around the outside of the tube liner and enters the coolant channel near the end of the liner.

In addition to the temperature sensors, other instruments and sensors provide test data and control information on important parameters. These include:

- (a) Strain gages on the tie rod to provide a continuous indication of tie rod load during the test.
- (b) Linear displacement gage on the cold end of the cluster to monitor axial movement of the cluster because of pressure surges and thermal expansion.

- (c) Pressure and flow rate instrumentation on the inlet and outlet of both hydrogen and helium streams.

The cluster model is tested in the CL-1 furnace which is a jacketed, water-cooled pressure vessel with water-cooled electrodes at each end. The furnace liners and shell are protected from the high temperature of the fuel elements by a series of graphite and molybdenum radiation shields. To protect these graphite components from hydrogen corrosion, a protective helium blanket is maintained in the furnace body. This is accomplished by introducing the helium at a slightly higher pressure than the hydrogen (2 to 5 psi). The helium blanket inhibits corrosion on the outer surfaces of the elements so that precise reactor fuel element environmental simulation is not achieved. The support block and related hardware is not effected by this helium flow because it leaves the furnace body at a point upstream from the block. Pyrolytic graphite foil seals in the hot end chuck prevent the helium from flowing from the furnace body to the support block.

With the above configuration, steady-state test durations of from 20 to 30 minutes with a cluster exit gas temperature of 4300°R are practical. In general, element failure is the limiting factor. The failure can be from bore or external corrosion, from electrical arcing, or from thermal and mechanical stresses. It is, therefore, necessary to use two or three test cycles, each with six new elements, to accumulate 60 minutes total test duration.

III REACTOR HARDWARE TESTS

A. Test Configurations

The cluster tests reviewed here were conducted in order to evaluate reactor support components and instrumentation for NRX-A6 and XE-1. An XE-1 exit gas thermocouple assembly was tested for a nominal 35 minutes as a qualification for inclusion in XE-1. Three (3) NRX-A6 support block and protection cup configurations were evaluated in developmental tests. The test configurations and the test numbers and dates are summarized in Table 1.

These tests were conducted at a hydrogen flow rate somewhat higher than in previous tests of NRX-A5 and XE-1 components. A total mass flow rate of about 0.12 lb/sec was employed with a cluster pressure drop of about 45 psi and a cluster exit pressure of 565 psia. This resulted in an increase in power to a level of 2.1 MW. Control of the tests was based on either cluster exit gas temperature (in the case of the XE-1 tests) or on the mixed mean gas temperature of the tie rod and cluster gas streams (in the cases of NRX-A6 tests). The values of mixed mean temperature calculated from flow rates and individual gas stream (tie rod and cluster) temperatures agreed with measured mixed mean temperatures to within $\pm 40^{\circ}\text{R}$ for the XE-1 tests.

A direct gas inlet plenum was employed to separate main cluster hydrogen flows from the helium purge employed on the outside of the cluster to protect the furnace parts. An additional change from former cluster test operation was the

WANL-TME-1624

TABLE 1
TEST SUMMARY

Test Number	Support Configuration	Test Date
FFL-1.a.0001a	NRX-A6 skirtless block, double vapor-deposited tungsten protection cup, coated ATJ support washer, regular insulating cup; "spigotted" insulating sleeves.	11-3-66
FFL-1.a.0001b	Cycle 2 of above.	11-12-66
FFL-1.a.0002a	NRX-A6 skirtless block, coated ATJ protection cup, coated ATJ support washer, regular insulating cup, "spigotted" insulating sleeves.	10-7-66
FFL-1.a.0002b	Cycle 2 of above.	10-17-66
FFL-1.a.0002c	Cycle 3 of above.	10-25-66
FFL-1.a.0004a	XE-1 exit gas thermocouple assembly, hollow tie rod, molybdenum liner cup, skirted block and related hardware, "spigotted" insulating sleeves, inconel orifice sleeve, molybdenum baffle.	10-22-66
FFL-1.a.0005a	Same configuration as 4a except inconel sleeve changed to molybdenum and modified dimensionally.	10-31-66
FFL-1.a.0005b	Cycle 2 of above.	11-9-66
TFL-1.a.0006a	75 NbC/25C composite protection cup (LASL material); 937J913 G01, skirtless block; 979D795 H01 support washer; 979D488 H01 insulating cup.	1-17-67
TFL-1.a.0006b	Cycle 2 of above.	1-25-67
TFL-1.a.0006c	Cycle 3 of above.	2-7-67

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

TABLE I (Continued)

<u>Test Number</u>	<u>Support Configuration</u>	<u>Test Date</u>
TFL-1.a.0006d	Cycle 4 of above.	2-13-67
TFL-1.a.0007a	MESK-00382 vapor deposited, regular tungsten protection cups (San Fernando Laboratory); 937J913 G01 skirtless block; 979D795 H01 support washer; 979D488 H01 insulating cup.	1-20-67
TFL-1.a.0007b-1	Cycle 2 of above.	2-1-67
TFL-1.a.0007b-2	Cycle 3 of above.	2-2-67

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

use of molybdenum radiation shields over the last 15 inches of the cluster. Further, orificing was altered slightly so that 36 mil orifices were employed in the inner circle of cluster flow channels with 33 mil orifices in intermediate radial channels and 30 mil orifices in the peripheral channels.

These and other changes in cluster test operation contributed appreciably to a better simulation of temperature profiles in the full reactor tests. Figure 2 illustrates this fact by comparing the observed fuel surface temperatures in this series of cluster tests with maximum fuel temperature calculated for NRX-A5 at a power factor of one. The values plotted with circles are averages for the sixteen tests reported herein.

The individual tests and post-test results are discussed below.

B. Summary of Test Results

Table II provides a list of reactor grade parts employed in each cluster test. The individual serial numbers are listed in Table III. Tables IV and V summarize the test conditions and results including weight loss data. As noted in previous reports, one should exercise caution in the use of weight loss data in that the cumulative losses shown represent coating losses, corrosion losses, and deposition of material from upstream in the cluster. The "equivalent times" at 4283°R are based on the reaction rate of carbon and hydrogen to form methane. They are provided as a convenient means of comparing the total "reaction time" at 4283°R of graphite components. For metal components, the "duration at steady-state" is

FIGURE 2

COMPARISON OF AXIAL TEMPERATURE PROFILES FOR
TFL-1a CLUSTER TEST AND NRX-A5

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

TABLE II

Reactor Components Employed in Cluster Tests

Part Description	Quantity per Cluster	Part Number	TFL-1.a.000 Tests in Which Used
Fuel Elements	6	XE-1 or NRX-A5 Grade	All
Split Bushing	1	946C216 HO2	1, 2, 6, 7
Split Bushing	1	946C216 H14	4, 5
Compression Spring	1	978D695 HO1	All
Spring Shim	1 to 10	946C684 HO1	All
Tie Rod (Solid)	1	945C568 HO1	1, 2, 6, 7
Tie Rod Assembly (Hollow)	1	980D455 GO1	4, 5
Tie Rod Nut	1	946C053 HO1	1, 2, 6, 7
Tie Rod Nut	1	946C670 HO1	4, 5
Tie Rod Pin	1	963B339	1, 2, 6, 7
Tube Liner	1	978D347 HO8E	All
Insulating Sleeve, Counter-Sunk	1	946C970 HO2	All
Insulating Sleeve, Tapered	2	946C120 HO1	All
Insulating Sleeve, Tapered	2	946C121 HO1	All
Insulating Sleeve, Straight	1	979D887 HO1	All
Insulating Sleeve, Straight	11	979D887 HO2	All
Insulating Sleeve, Straight	1	979D887 HO3	All
Tube Liner Adapter	1	978D351 HO1	All
Support Cone	1	976D449 HO1	1, 2, 6, 7
Insulating Washer	1	963B257 HO1B	All
Insulating Cup	1	979D488 HO1A	1, 2, 6, 7
Insulating Cup	1	978D626 HO3D	4, 5
Support Washer, ATJ	1	978D960 HO1	2
Support Washer, ATJ	1	979D795 HO1	1, 6, 7
Support Washer, ATJ	1	978D960 HO3D	4, 5
Protection Cup	1	978D959 HO1	2
Protection Cup	1	ME-SK-00382	1, 7
Pyrofoil Washers	10	947C043 HO1	4, 5
Support Block	1	909E371 H1OP	4, 5
Support Block	1	937J913 GO1	1, 2, 6, 7
Thermocouple Support Assembly	1	909E985 GO2	4, 5
Tungsten-Rhenium Thermocouple	1	979D149 HO2D	4, 5
Chromel-Alumel Thermocouple	1	978D186 HO1	All
Liner Cup	1	979D497 HO2A	4, 5
Molybdenum Spacer	1	947C291 HO1	4, 5
Orifice Sleeve	1	980D466 HO1	5
Baffle	1	980D454 HO1 (ME-SK-00439)	4, 5

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

TABLE III
COMPONENT IDENTIFICATION

Component	----- TFL-1.a.000 Test Number -----							
	1a	1b	2a	2b	2c	4a	5a	5b
B Element	AC-99-30956	UN-99-73048	UN-99-73894	UN-99-97051	UN-99-73926	PF-6961	PF-3497	PF-6819
C Element	AC-99-31053	UN-99-73175	UN-99-73371	UN-99-97179	UN-99-73204	PF-3536	PF-3233	PF-3695
D Element	AC-99-31136	UN-99-73192	UN-99-74783	UN-99-97392	UN-99-74292	PF-3211	PF-3241	PF-5198
E Element	AC-99-31346	UN-99-73193	UN-99-74368	UN-99-98086	UN-99-73944	PF-5087	PF-3336	PF-4256
F Element	AC-99-31559	UN-99-73220	UN-99-73236	UN-99-98218	UN-99-74271	PF-5455	PF-3852	PF-3514
G Element	AC-99-25923	UN-99-73222	UN-99-73691	UN-99-98341	UN-99-74254	PF-3534	PF-4512	PF-0740
Support Block	A50348	A50348	A50335	A50335	A50335	A31729	A31723	A31723
Insulating Cup	LB1857	LB1857	LB885-21	LB885-21	LB885-21	LB1855-T7	LB1855-M11	LB1855-M11
Insulating Washer	LB1590	LB1590	521-8	521-8	521-8	521-8	528-1	528-1
Support Washer	(Pos 1-12)	(Pos 1-12)	LB2384	LB2384	LB2384	LB2372-3	LB2384-N9	LB2384-N9
Protection Cup			LB2720-21	LB2720-21	LB2720-21			
Tie Rod	43G	43G	33G	33G	9G	20U	5U	5U
Exit Gas Thermocouple						A49839	A48840	A48840
Tube Liner Thermocouple	A40775	A40775	A40773	A40773	A40773	A40774	A40776	A40776
Pyrofoil Washers						LB2822	LB2822	LB2822
Aft Insulating Sleeve	LB1296	LB1296	LB1272	LB1272	LB1272	LB1181	LB1300	LB1300

Atomic Energy Act - 1954

CONFIDENTIAL
RESTRICTED DATA

12-A

TABLE III (Continued)
COMPONENT IDENTIFICATION

Component	TFL-1.a.000 Test Number					
	6a	6b	6c	6d	7a	7b
B Element	PF-5383	UN-99-96396	UN-99-96574	AC-89-32759	UN-99-73280	PF-4742
C Element	PF-7024	UN-99-96403	UN-99-97370	AC-89-32767	UN-99-73307	PF-4415
D Element	PF-6928	UN-99-96412	UN-99-97417	AC-89-32771	UN-99-73341	PF-4471
E Element	PF-1700	UN-99-96432	UN-99-97386	AC-89-32774	UN-99-73359	PF-4765
F Element	PF-6743	UN-99-96443	UN-99-97357	AC-89-32776	UN-99-73370	PF-4849
G Element	PF-6619	UN-99-96447	UN-99-97368	AC-89-32770	UN-99-73470	PF-4746
Support Block	A52626	A52626	A52626	A52626	A52594	A52594
Insulating Cup	LB885	LB885	LB885	LB885	LB885	LB885
Insulating Washer	LB1590	LB1590	LB1590	LB1590	LB1590	LB1590
Support Washer	LB3391	LB3391	LB3391	LB3391	LB3391	LB3391
Protection Cup	IT-4	IT-4	IT-4	IT-4	66-10-101	66-10-101
Protection Cup	--	--	--	--	66-10-144	66-10-144
Tie Rod	35G	35G	36G	36G	80G	80G
Exit Gas Thermocouple	--	--	--	--	--	--
Tube Liner Thermocouple	A40778	A40778	A40778	A40778	A49041	A49041
Diffuser Thermocouple	--	S/N A496	S/N A49592	S/N A49598	--	S/N A49603
Pyrofoil Washers	--	--	--	--	--	--
Aft Insulating Sleeve	LB1291	LB1291	LB1291	LB1291	LB1291	--

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

WANT-TME-1624

 Astronuclear
Laboratory

TABLE IV
TEST CONDITIONS AND RESULTS

	TFL-1, a. 000															
	Test Number															
Parameter	1a-1	1a-2	1b	2a	2b	2c	4a	5a	5b	6a	6b	6c	6d	7a	7b-1	7b-2
Test Duration, min.	18.0	11.0	16.0	24.0	40.0	32.0	34.0	35.0	29.0	27.85	31.8	8.4	28.7	39.0	7.17	34.6
Equivalent Time at 4283°R, min.	7.8	4.7	6.9	19.8	33.6	25.7	23.9	21.4	18.8	----	----	----	----	----	----	----
Duration at Steady-State, min.	5.5	2.5	4.3	17.0	28.0	21.0	21.0	20.2	16.5	21.0	23.5	0	19.9	29.9	0	28.0
Support Block Temperature, °R	(4340)	(4340)	(4300)	(4430)	(4400)	(4310)	(4230)	(4290)	(4410)	(4250)	(4300)	(4050)	(4200)	(4330)	(4250)	(4370)
Cluster Exit Gas Temperature, °R	----	----	----	----	----	----	4290	4280	4340	----	----	----	----	----	----	----
Mixed Mean Temperature, °R	4060	4090	4015	4140	4120	4020	3950	4010	4120	3960	4020	3780	----	4040	3960	4080
Element Surface Temperature, °R																
Station 43	4560	4500	4600	----	4280	4640	4620	4450	4710	4630	4710	----	4510	4630	----	4770
Station 35	4220	4380	4290	4290	4190	(4350)	4200	4220	4450	----	4370	----	4020	4160	----	4400
Station 16	2720	2780	2740	2880	----	(2900)	----	2590	2750	2510	2660	----	2395	3310	----	2930
Station 8	(1500)	(1500)	(1500)	(1500)	2370	(2750)	(1500)	(1500)	(1500)	----	2220	----	----	----	----	2510
Tie Rod Exit Gas Temperature, °R	957	966	1014	1066	1045	1066	966	1000	1000	935	1001	904	996	926	909	979
Hydrogen Flow Rate, lbm/sec	0.120	0.121	0.120	0.122	0.120	0.120	0.122	0.123	0.123	0.133	0.132	0.132	0.120	0.130	0.132	0.119
Helium Flow Rate, lbm/sec	0.01135	0.01135	0.00698	0.00635	0.00585	0.00860	0.00920	0.00645	0.00860	0.00223	0.00154	0.00947	0.00176	0.00418	0.00154	0.00192
Cluster Exit Pressure, psia	563	567	565	562	565	564	562	562	565	576	569	584	569	569	560	569
Cluster Pressure Drop, psi	45	43	45	43	41	47	43	44	45	475	50	35	40	49	25	39
He/H ₂ Pressure Drop, in. H ₂ O	30	30	45	40	40	40	40	35	30	100+	80	65	75	33	100+	50
Electrical Power Input, MW	2.15	2.09	2.04	2.18	2.11	2.21	2.03	2.22	2.16	2.18	2.23	2.46	2.05	2.22	2.31	2.18
Resistance, milliohms	7.96	8.09	8.56	8.38	8.14	7.52	6.63	7.14	6.66	6.1	9.64	9.19	7.90	7.14	6.13	7.25
Voltage, volts	131	130	132	135	131	129	116	126	120	120	145	150	127.5	132.5	125	125
Current, kilo amps	16.45	16.10	15.40	16.10	16.10	17.15	17.50	17.68	18.02	18.30	15.40	16.45	16.10	16.80	18.55	17.50
Tie Rod Pre-load, lbf	300	300	300	328	297	325	275	325	325	325	325	300	300	300	300	300
Maximum Tie Rod Load, lbf	535	530	540	609	576	640	(326)	----	----	562	660	590	590	570	----	----
Tie Rod Orifice Diameter, mils	52	52	52	52	52	52	73	73	73	52	52	52	52	52	52	52
Maximum Axial Displacement, in.	0.500	0.500	0.500	0.100	----	0.500	0.220	0.500	0.500	0.500	0.210	0.500	0.310	0.470	0.470	0.500

TABLE V
SUMMARY OF CUMULATIVE WEIGHT LOSS DATA

		TFL-1.a.000 Test Number													
COMPONENT	LOSS	1a	1b	2a	2b	2c	4a	5a	5b	6a	6b	6c	6d	7a	7b
Support Block	Grams	-	5.02+	-	-	18.94+	2.18	-	5.87	-	-	-	6.40**	-	5.57+
	% of Initial	-	3.47	-	-	14.82	1.23	-	3.33	-	-	-	5.36	-	3.80
Support Washer	Grams	-	-	-	-	-	0	-	0	-	-	-	Welded to Block	-	Welded to Block
	% of Initial	-	-	-	-	-	0	-	0	-	-	-	-	-	-
Insulating Cup	Grams	-	0.23	-	1.19	1.37	0.27	-	0.52	-	-	-	0.41	-	0.656
	% of Initial	-	7.85	-	30.13	34.68	9.31	-	17.63	-	-	-	13.47	-	22.00
Pyrofoil Washers	Grams	-	-	-	-	-	0.020	-	0.055	-	-	-	-	-	-
	% of Initial	-	-	-	-	-	2.86	-	7.10	-	-	-	-	-	-
Aft Insul. Sleeve	Grams	-	0	-	0.06	1.07	1.23	-	0.42	-	-	-	0.29	-	0.56
	% of Initial	-	0	-	0.86	15.35	15.41	-	6.03	-	-	-	4.16	-	8.02
Insulating Washer	Grams	-	0	-	0	0	0	-	0.01	-	-	-	0.01	-	0.002
	% of Initial	-	0	-	0	0	0	-	1.69	-	-	-	1.67	-	0.33
Center Element	Grams	-	0.9	-	12.9	0++	5.50	-	14.4	-	11.00	0	3.20	4.00	28.60
	% of Initial	-	0.33	-	4.76	0	1.99	-	5.21	-	4.03	0	1.16	1.47	10.53
Protection Cup	Grams	-	-	-	-	-	-	-	-	-	-	-	0.05	-	Welded to Washer
	% of Initial	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Six Fuel Elements*	Grams	25.5	15.3	26.6	99.2	94.0	40.9	56.0	50.2	33.00	69.00	41.10	37.60	72.10	176.60
	% of Initial	0.59	0.36	0.62	2.32	2.17	1.06	1.47	1.32	0.87	1.63	0.97	0.91	1.67	4.65

* Not cumulative for fuel elements.

** Block Plus support washer.

+ Includes block, support washer, and protection cup.

++ Changed after 2b

WANT-TME-1624

Astronautics
Laboratory

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

a more appropriate parameter for evaluation of components. The "test durations" represent total operating time under conditions of applied power, including all intermediate power holds, steady-state operation, and power ramps.

C. XE-1 Component Qualification Tests

Tests TFL-1.a.0004a, TFL-1.a.0005a, and TFL-1.a.0005b were evaluations of exit gas thermocouple assembly designs for XE-1 which differed in several respects from previous designs (TME-1375 and TME-1511).^{1,2} In order to prevent hot gases from flowing through the slot on the molybdenum liner cup and subsequently impinging on the thermocouple support and tie rod extended cone, a molybdenum baffle or curved plate was added. This plate was installed with a relatively close fit over the thermocouple support as shown in Figure 3 which illustrates the assembly for test 5. In addition to this baffle, a slotted collar or orifice sleeve was installed over the end of the tie rod cone to provide a flow impedance for the tie rod exit gas flow. This sleeve not only diverted a large portion of the tie rod flow over the thermocouple transition joint but also maintained a slight overpressure within the molybdenum liner cup to insure that hot gases would not tend to flow inward toward the transition joint and tie rod cone. The orifice sleeve was at first designed to be threaded over the tie rod extended cone as shown in Figure 4 for test TFL-1.a.0004. Subsequently the non-threaded design in Figure 3 was employed and the material changed from inconel to molybdenum.

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

**CONFIDENTIAL
RESTRICTED DATA**
Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

FIGURE 3

EXIT GAS THERMOCOUPLE ASSEMBLY
FOR TEST TFL-1a.0005

**CONFIDENTIAL
RESTRICTED DATA**
Atomic Energy Act - 1954

FIGURE 4

EXIT GAS THERMOCOUPLE ASSEMBLY
FOR TEST TFL-1a.0004

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

WANL-TME-1624

A third modification of the previous thermocouple assembly design was the use of a molybdenum bushing or spacer around the thermocouple tip inside the molybdenum support. This spacer moved the transition joint away from direct contact with the thermocouple support and acted as an impedance to the conduction of heat along the thermocouple sheath toward the transition joint.

Test 4a was successfully conducted at a cluster exit gas temperature of 4290°R for a total steady-state full power hold of 21.0 minutes. The thermocouple operated continuously throughout the entire power cycle of 34.0 minutes which included start-up and shut-down power ramps and holds at intermediate power levels. The thermocouple and other support hardware operated adequately throughout the test.

Post test inspection of the assembly revealed that the thermocouple and support were essentially intact but the molybdenum liner cup, tie rod cone, and inconel sleeve were locally melted as shown in Figure 5. Analysis of the configuration design resulted in the conclusion that the clearance between the orifice sleeve and molybdenum cup was too small. The cup apparently touched the sleeve during the test and the heat flux by conduction through the molybdenum cup melted the sleeve and tie rod cone. When the molten metal from the cone and sleeve wet the molybdenum cup, a lower temperature eutectic was formed between the molybdenum and the inconel which subsequently resulted in the melting of portions of the molybdenum cup.

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

FIGURE 5

THERMOCOUPLE ASSEMBLY, LINER CUP, AND TIE ROD
AFTER TEST TFL-1a.0004a

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

The orifice sleeve was redesigned for tests 5a and 5b. As noted previously, the sleeve was not threaded onto the tie rod cone. In addition, the material was changed from inconel to molybdenum and the clearance between the sleeve and liner cup was increased. The increased clearance was to prevent contact with the liner cup while maintaining adequate flow impedance for the tie rod exit gas flow to cool the thermocouple braze joint.

Both cycles were successfully completed in test 5 so that a total time under power of 64 minutes was attained. The thermocouple responded to all temperature changes throughout both cycles and recorded continuously. A maximum temperature of 4350°R was recorded for test cycle 5b and the thermocouple was held at this temperature for about 6 minutes. The total steady-state operating time for both test cycles at temperatures of 4283°R and above was 36.7 minutes.

Figure 6 illustrates the fact that no damage was sustained by any of the components of the thermocouple assembly as a result of the two power cycles.

On the basis of these tests as well as evaluations performed by Reactor Design, Reactor Analysis, and Instrumentation and Control departments, the assembly was qualified and approved for inclusion in the XE-1 assembly.

D. NRX-A6 Component Development Tests

Three (3) developmental NRX-A6 axial support configurations were evaluated in support of the design of the NRX-A6 reactor support system. These configurations were the composite (75 NbC/25C) protection cup with the skirtless block, the

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

FIGURE 6

THERMOCOUPLE ASSEMBLY, LINER CUP, AND TIE ROD
AFTER TEST TFL-1a.0005b

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

double tungsten protection cup with the skirtless block, and the ATJ protection cup with the skirtless block. All cups were for a regular, uninstrumented cluster. These support configurations were tested for a nominal 60 minutes endurance at 4300°R exit gas temperature in several cycles as shown in Table I.

The purpose of these tests was to investigate the ability of the cups to withstand the following environmental conditions:

1. High flow (0.13) lb/sec. hydrogen), high temperature (4300°R) environment for one (1) hour at a nominal axial load of 550 lbf.
2. Erosive environment typical of element "end-of-life" operation.
3. Rapid cool-down transient (300°R per second nominal).

The criteria which were to be used to evaluate the cup materials were physical appearance (coating loss, cracks, dimensional changes), degree of carbide formation on the tungsten cups, and degree of material depletion for the composite cup and ATJ cup.

1. ATJ Cup

The skirtless block and coated ATJ protection cup configuration was evaluated by tests TFL-1.a.0002a, b, and c. These tests were successfully completed in total power cycles of 24.0, 40.0, and 32.0 minutes. The total equivalent operating time at the design temperature of 4283°R was 79.1 minutes for the three cycles. Actual steady-state operating time at full power was 66.0 minutes.

The full power tie rod loadings for the three cycles were 609, 576, and 640 lbf respectively. These loadings were achieved by a combination of a pre-load of about 300 lbf using a special spring assembly and by the expansion of the elements at the full power material temperatures shown in Figure 1. Average power was about 2.17 MW. Tie rod exit gas temperatures of up to 1066°R were recorded.

Figure 7 shows that, with the exception of some coating loss on the insulating cup, the support block and other components were not damaged during the first cycle. The block, ATJ cup, and support washer were welded together, however.

Test cycle 2b resulted in more apparent damage to the support components as shown in Figure 8. The coating was lost over the entire outer surface of the insulating cup. In addition welding between the block and two of the elements removed about one third of the coating from the top of the block. Further, the block was cracked axially in several places where the thin cross section occurs between the block periphery and the outermost flow channels. Figure 9 is a close-up of these cracks.

The ATJ cup itself was not damaged during cycle 2b. The coating did not appear to be chipped or cracked and no subsurface corrosion was apparent after a total equivalent time at 4283°R of 53.4 minutes.

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

FIGURE 7

SKIRTLESS BLOCK AND ATJ CUP AFTER 19.8 MINUTES
AT 4283 °R (TFL-1a.0002a)

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

FIGURE 8

SKIRTLESS BLOCK AND ATJ CUP AFTER 53.4 MINUTES
AT 4283 °R (TFL-1a.0002b)

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

FIGURE 9

AXIAL CRACKING OF SKIRTLESS BLOCK FROM TFL-1a.0002b

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

WANL-TME-1624

The third test cycle damaged the block somewhat more severely because of the loss of coating in the previous test cycle. However, the system continued to operate successfully throughout the test. The actual weight loss for the block, cup, and support washer was 14.8 percent, less than would be expected as a result of past experience with tests of blocks with coating damage. The insulating cup lost about 34.7 percent of its initial mass and the aft insulating sleeve lost about 15.4 percent.

Although the protection cup could not be examined and weighed separately because it was welded to the block, there were obvious pockets of corrosion near the trailing edge. Some coating was missing from the outer surface. These observations as well as those which apply to the block are illustrated by Figures 10, 11, and 12.

2. Tungsten Cups

The first attempt to evaluate the support system consisting of a skirtless block and two vapor-deposited tungsten protection cups for 60 minutes at 4300°R was only partially successful. In test TFL-1.a.0001a, a hydrogen leak in the flow system resulted in a test termination short of the scheduled 20 minutes at full power. In cycle 1b a water leak in the furnace caused a corresponding test termination after a short period at full power. Substantial amounts of coating were lost on the periphery of the block after cycle 1b and no further tests were attempted.

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

FIGURE 10

SKIRTLESS BLOCK AFTER 79.1 MINUTES AT 4283°R
TOP VIEW (TFL-1a.0002C)

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

FIGURE 11

SKIRTLESS BLOCK AND ATJ CUP AFTER 79.1 MINUTES
AT 4283°R (TFL-1a.0002c)

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

FIGURE 12

SKIRTLESS BLOCK, ATJ CUP, AND RELATED HARDWARE
FROM TFL-1a.0002c

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

WANL-TME-1624

The total operating time for the two power cycles including all power ramps and holds was 45 minutes. This provided a total steady-state time at 4283°R of 12.5 minutes. All observed test parameters were normal: fuel temperature profiles were like those shown on Figure 1; mixed mean gas temperatures were about 4050°R; tie rod exit gas temperatures were about 980°R; tie rod loadings were 535 lbf; and all power and flow parameters were as specified.

Figure 13 shows that the tungsten cup was not damaged during these test cycles. Welding of the cups, support washer, and block took place. The damage on the block shown in Figure 13 is partly a result of the handling of the cluster during removal from the furnace. The damage is also a direct result of the test cycles since the coating loss occurred in both test cycles. In the first, most of the coating was cracked and raised. In the second cycle, much of the already lifted coating was lost. No explanation for the poor coating adherence has been found.

The metallographic analysis of the tungsten cup from test TFL-1.a.0001 indicated that welding between the two cups and between the cup and washer had occurred. The analysis also showed carbiding of the inside surface of the larger cup adjacent to the insulating cup, which had lost most of its niobium carbide coating. Figure 14 shows the welded section on the flanges of the cups. Figures 15 and 16 are photomicrographs of the wall areas showing the relatively light carbiding of the tungsten.

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANI-TME-1624

FIGURE 13

SKIRTLESS BLOCK AND TUNGSTEN CUPS AFTER 18.5 MINUTES
AT 4283°R (TFL-1a.0001b)

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

Astronuclear
Laboratory

WNL-TME-1624

FIGURE 14

50X CROSS SECTION OF FLANGE AREA
OF TUNGSTEN CUPS TFL-1a.0001

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

FIGURE 15

50X CROSS SECTION OF WALL AREA ON
SMALL TUNGSTEN CUP TFL-1a.0001

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

FIGURE 16

50X SECTION OF WALL AREA OF LARGE TUNGSTEN CUP
TFL-la.0001

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

WANL-TME-1624

A second set of tungsten cups were evaluated in test TFL-1.a.0007. These cups, which were manufactured by San Fernando Laboratories, were tested in three power cycles. In the first, all parameters were held on control for 30 minutes and the test was terminated normally. In the second cycle, the test was terminated rapidly (280°R/sec) as it reached full power because of a current over-ride on the power supply. The test was restarted and held at steady-state at a somewhat lower flow rate for 28 minutes. A moderately fast cool-down (150°R/sec) followed when diagnostic instrumentation indicated that several elements were failing because of corrosion damage.

Figure 17 shows that neither the block nor cup were damaged during the first 30 minute cycle. Welding of the support washer, block, and two cups occurred. Figure 18 shows the minimal damage after the last cycle for the block, cups, and aft insulating sleeve.

The insulating cup lost about 22 percent of its initial weight, including coating. The aft insulating sleeve lost about 8 percent. The block, cup, and support washer lost 4 percent of their combined weights. Attributing this total weight loss only to the block results in an estimated block loss of 5 percent.

Post-test inspection and sectioning showed no cracks or other physical damage to the tungsten cups. The outer diameter increased by about 1% (8 mils) as a result of the axial load and high temperatures. These dimensional changes are tabulated in Table VI.

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

Astronuclear
Laboratory

WANI-TME-1624

FIGURE 17
SKIRTLESS BLOCK AND TUNGSTEN CUPS AFTER 29.9 MINUTES
AT 4300°R (TFL-1a.0007a)

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

WANL-TME-1624

FIGURE 18
SKIRTLESS BLOCK AND TUNGSTEN CUPS AFTER 57.9 MINUTES
AT 4300°R (TFL-la.0007b)

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

Metallographic examination of the tungsten cups, support block, and washer substantiated the earlier observations that welding between these components had occurred and that no appreciable damage was sustained by any component. Carbiding of the tungsten cups on the inside surfaces took place to a depth of about 30 percent of the wall cross section. These observations are shown in Figures 19 through 22.

3. Composite Cup

Four (4) test cycles were required to provide the nominal 60 minute endurance test. The first test was on control for 21 minutes before a temperature limit switch on the power supply resulted in a power shut-down and a corresponding rapid cool-down of $270^{\circ}\text{R}/\text{sec}$. The block and cup were not damaged visibly; however, welding of the cup, support washer, and block took place.

The second cycle was also on control until 24 minutes after full power had been attained at which time a rapid shut-down ($270^{\circ}\text{R}/\text{sec}$) occurred because of broken fuel elements in the cluster. The third cycle again was terminated rapidly because of broken elements just as full-power was attained. Both of these cycles represented "end-of-life" conditions in that considerable debris from the broken cluster passed over the cups. Although some carbon deposited on the cup, as shown in Figure 23, no visible damage occurred during these two cycles with the exception of small coating chips on the upstream edges of the lobes on the block.

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

TABLE VI
SUMMARY OF PRE AND POST-TEST
DIMENSIONS OF PROTECTION CUPS

DIMENSION *	TFL-la.000 TEST NUMBER					
	6a	6b	6c	6d	7a	7b
D1 BEFORE (LOADED)	.8697	.8697	.8693	.8697	.8111	.8123
D1 AFTER (LOADED)	.8697	.8700	.8698	.8697	.8123	.8143
D1 AFTER (NOT LOADED)						.8153
D2 BEFORE (LOADED)	.8698	.8697	.8698	.8700	.8106	.8138
D2 AFTER (LOADED)	.8697	.8697	.8698	.8698	.8138	.8167
D2 AFTER (NOT LOADED)						.8165
D3 BEFORE (LOADED)	.8693	.8697	.8700	.8697	.8160	.8213
D3 AFTER (LOADED)	.8693	.8707	.8697	.8700	.8213	.8297
D3 AFTER (NOT LOADED)						.8287
G BEFORE (LOADED)	.0143	.0137	.0133	.0133	.0107	.0087
G AFTER (LOADED)	.0127	.0137	.0120	.0130	.0097	.0057
G AFTER (NOT LOADED)						-

* AVERAGE OF 3 AT 120° APART

WANL-TME-1624

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

FIGURE 19

KEY TO PHOTOMICROGRAPHS OF COMPOSITE AND TUNGSTEN CUPS
FROM TESTS TFL-la.0006 AND TFL-la.0007

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

FIGURE 20

SECTIONAL VIEWS OF TUNGSTEN CUPS, SUPPORT BLOCK, AND
WASHER FROM TEST TFL-1.a.0007

WANL-TME-1624

FIGURE 21
SECTIONAL VIEWS 2 AND 3 OF TUNGSTEN CUPS FROM
TFL-1.a.0007

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

FIGURE 22

SECTIONAL VIEWS 4, 5 , AND 6 OF TUNGSTEN CUPS
FROM TFL-1a.0007b

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

FIGURE 23

SKIRTLESS BLOCK AND COMPOSITE CUP AFTER 44.5
MINUTES AT 4300°R (TFL-1a.0006c)

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

WANL-TME-1624

In the fourth cycle, 20 minutes of steady-state operation was followed by a normal shut-down ($40^{\circ}\text{R}/\text{sec}$). Figure 24 illustrates the degree of visible damage to the block, cups, and aft insulating sleeve. The corrosion pockets in the block were a direct result of the coating chips in the previous cycle. The block lost about 5 percent of its weight while the insulating cup and insulating sleeve lost 13 and 4 percent respectively.

Post-test inspection of the cup showed a weight loss of less than 0.5 percent. Its dimensions were unchanged as shown in Table VI. The metallographic examination revealed several facts: The block, cup, and washer had been welded but came apart when the coating on the washer peeled off. No substantial loss of graphite occurred except where coating cracks exposed the substrate material. Only at the edges of the cup walls did any appreciable amount of graphite corrode from the matrix. These observations are shown in Figures 19, 25 and 26.

Several hairline cracks were discovered on the outside surface of the cup and on the flange. These are shown in Figure 27. It is possible that these cracks were caused by the uneven loading of the cup flange in the last cycle. This was a result of the peeling of coating on the support washer and transfer of coating to the cup flange in cycle 6c. A slight misalignment during reassembly for cycle 6d may have caused an uneven mating surface which overstressed the cup.

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

FIGURE 24

SKIRTLESS BLOCK, COMPOSITE CUP, AND RELATED HARDWARE
AFTER 64.4 MINUTES AT 4300°R (TFL-la.0006d)

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

FIGURE 25

SECTIONAL VIEWS OF SKIRTLESS BLOCK, COMPOSITE CUP,
AND WASHER FROM TFL-1a.0006d

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

WANL-TME-1624

FIGURE 26

50X SECTIONAL VIEWS 9 AND 10 OF COMPOSITE CUP FROM
TFL-1a.0006d

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

Astronuclear
Laboratory

WAL-TME-1624

FIGURE 27

100X SECTIONAL VIEWS 11, 12 AND 13 OF COMPOSITE CUP
FROM TFL-1a.0006d

**CONFIDENTIAL
RESTRICTED DATA**

Atomic Energy Act - 1954

WANL-TME-1624

IV SUMMARY AND CONCLUSIONS

Employing design changes previously made on the cluster test model, sixteen (16) cluster tests were conducted to evaluate reactor support hardware for NRX-A6 and XE-1. The XE-1 tests were to qualify the exit gas thermocouple assembly for inclusion in XE-1 and the NRX-A6 tests were developmental evaluations of the skirtless block with three types of protection cup configurations. These were a coated ATJ graphite cup, a composite (75/25 niobium carbide to graphite) cup, and vapor deposited tungsten cups.

The exit gas thermocouple assembly was qualified for inclusion in XE-1 by successful completion of a nominal 35 minute endurance at a steady-state temperature level of 4283°R or above. The assembly remained structurally sound throughout the test and thermocouple output was continuous and accurate.

The three NRX-A6 configurations were each tested for nominal 60 minute endurance tests at 4300°R exit gas temperature. All three support configurations remained structurally adequate throughout the tests at axial tie rod loads between 500 and 650 lbf. The support block from one test was corroded severely from a coating loss in disassembly from a previous cycle but continued to support the cluster adequately for the remaining life requirement.

The ATJ protection cup lost coating during the last power cycle but remained structurally sound after 60 minutes. The tungsten cups were virtually undamaged, but were carbided on the inner surfaces to a depth of about 30 percent

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

of the wall thickness. The carbide cup was essentially intact in terms of coating losses and corrosion of graphite from the matrix. However, it was partially cracked in the area of the support flange.

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1624

V BIBLIOGRAPHY

1. WANL-TME-1511, "Single Cluster Corrosion Test Summary, April 1966 to September 1966", L. A. Salvador, September 1966.
2. WANL-TME-1375, "Single Cluster Corrosion Test Summary, August 1965 to March 1966", L. A. Salvador, R. D. Foster, L. Wagner, April 1966.
3. WANL-TME-1389, "NRX-A5 Reactor Analysis Data", Thermal & Nuclear Design Department Staff, April 1966.

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

RECEIVED

1967 JUN 19 PM 3:12

SNPO-C

CLEVELAND, OHIO