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Westinghouse
Astronuclear
Laboratory

SNPO-C

WANL-TME-2742
SEPTEMBER 1970

DATA ITEM T-119

CORE PERIPHERY MODEL

TEST 64DT-211 (U)

FINAL REPORT

MASTER

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CORE PERIPHERY MODEL U

TEST 64DT-211 (U)

FINAL REPORT

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ABSTRACT

(CRD) The cyclic corrosion resistance capability of an R-1 type periphery featuring a multiple layer Z-liner thermalized rerolled pyrofoil wrapper was experimentally measured. This test employed an SX-5 graphite core and simulated fuel elements. These materials simulate the growth characteristics of the high expansion fuel proposed for the R-1 design. The results obtained in this test are similar to those obtained in the 64DT-212 test with the thermalized wrapper thermalized in-place. This test further substantiates the low probability for this full length wrapper concept to achieve the R-1, 10-hour lifetime requirement. Good agreement was realized between the measured test data and the predicted thermal/hydraulic conditions. Corrosion damage to the pyrofoil wrapper appears to originate largely in the butt joints between adjacent Z-liners. This indicates significant amounts of hydrogen leakage through these joints and higher corrosion rates for pyrofoil than had been expected prior to the 64DT-211 and 64DT-212 tests. Examination of the wrapper O. D. shows that no measurable corrosion damage occurred at temperatures below 2400°R.

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1.0 INTRODUCTION

1.1 TEST IDENTIFICATION

1.1.1 Type of Report

This report is a final report.

1.1.2 Applicable Scope of Test Document

The applicable Scope of Test Document Number is 64DT-211, Rev. 1, "TFFL2a.0004b Corrosion Test".

1.1.3 Functional Category of Test

This is a development test to provide corrosion resistance capability and provide a qualitative picture of the corrosion behavior of the wrapper.

1.1.4 Contractor

Westinghouse Astronuclear Laboratory (WANL/14683), under Subcontract NP-1, CY'70.

1.1.5 Test Facility and Location

This test was performed at the WANL Hydrogen Test Facility, Cell No. 1, Large, Pa., during these testing periods: Phase I, April 7, 1970 through April 21, 1970; Phase II, May 4 and 5, 1970.

1.2 PURPOSE

The objective of this test was to provide a qualitative picture of the corrosion behavior of the outside layer of a thermalized rerolled pyrofoil wrapper design at reactor wrapper O.D. temperature conditions.

2.0 REFERENCES

2.1 REFERENCES

2.1.1 Specification

EC-677564, Paragraphs 3.1.1.1.3 through 3.1.1.1.4 Performance/Design and Qualification Requirements Core Periphery for Nuclear Subsystem.

2.1.2 Data Item Description

Form 9, Data Item Description, T-119, dated April 2, 1969.

2.1.3 Drawing List

The following drawings describe the model and test components.

<u>Drawing No.</u>	<u>Sheet No.</u>	<u>Title</u>
711J745	1	General Assembly 64DT-211 (ALT) Filler Strip Corrosion Test

The following drawings are the wiring diagrams between the sensing and recording devices:

576F925	8	Thermocouple Locations
388D545	1	Possible Connection Options - Data Acquisition Trailer System for Thermocouples, Transducers, Strain and LVDT

The following drawings describe the flow system:

576F925	1	Overall FS-1 Flow Diagram
576F925	2	Basic Flow Loop
576F925	4	Basic Pneumatic Loop
576F925	5	Overall Pneumatic Loop
576F925	7	FS-1 Pneumatic Control System

2.2 DOCUMENTATION

<u>Document No.</u>	<u>Date</u>	<u>*By Dept.</u>	<u>Subject</u>
<u>2.2.1 Procedures</u>			
TFLP-104, Rev. L	4/9/70	TFFL	WANL Operating Procedure
<u>2.2.2 Test Information Sheets</u>			
TIS-DT-51.2A	4/7/70	TFFL	Test Plan For 64DT-211 Core Periphery Test
TIS-DT-51.2B	5/1/70	TFFL	Test Plan Revision
<u>2.2.3 Test Scope</u>			
64DT-211-0	1/2/69	RD	Scope of Test For TFL-2a.0004b Corrosion Test
64DT-211-1	4/8/70	RD	Test Scope Revision
<u>2.2.4 Data Release Memorandums</u>			
DRM 51252	3/6/70	TFFL	64DT-211 Final Assembly Measurements
DRM 51366	6/8/70	TFFL	64DT-031 Core Periphery Model Test Report
DRM 51377	7/30/70	TFFL	64DT-212 Core Periphery Model Test Report
DRM 51325	8/27/69	TFFL	Operating Test Directive For 64DT-317 (EP-1) Five-Inch Long Core Periphery Test Model
DRM 51353	3/9/70	TFFL	Operating Test Directive For 64DT-317 (EP-6) Five-Inch Long Core Periphery Test Model
DRM 51330	8/15/69	TFFL	Operating Test Directive For 64DT-317 (EP-5) Five-Inch Long Core Periphery Test Model
DRM 51369	8/14/70	TFFL	64DT- Core Periphery Test

* TFFL - Thermal & Fluid Flow Laboratory, TD- Thermal Design, RD- Reactor Design

<u>Document No.</u>	<u>Date</u>	<u>*By Dept.</u>	<u>Subject</u>
DRM 52110	10/29/69	TD	Thermal Analysis of the 64DT-211 Core Periphery Model
DRM 52110A	4/9/70	TD	Thermal Analysis of the 64DT-211 Core Periphery Model (Revision A)
DRM 52525	2/27/70	RD	Inter-Component Gaps, 64DT-211 Core Periphery Test.

2.2.5 Inner Office Memorandums

CE-1190	5/29/69	TFFL	Request for Analysis for 64DT-211 Core Periphery Test Model
CE-1212	7/25/69	TFFL	Request for Analysis for 64DT-211 Core Periphery Test Model. (Revision)
CE-1306	10/28/69	TFFL	Relocation of Thermocouples in 64DT-211 Core Periphery Corrosion Test
CE-1307	10/29/69	TFFL	Radial Expansion of the 64DT-211 Core Configuration
CE-1308	10/30/69	TFFL	64DT-211 Core Periphery Model Assembly
CE-1314	11/10/69	TFFL	64DT-211 Long Lead Loop Requirements
CE-1318	11/18/69	TFFL	Pyrofoil Shortage Status
CE-1322	11/24/69	TFFL	Pyrofoil for TFFL Core Periphery Models
TE-1347	1/23/70	TFFL	Pyrofoil 64DT-211 Core Periphery Corrosion Test
TE-1365	3/5/70	TFFL	64DT-211 Lateral Support Leakage as a Function of Inner Seal Movement
TE-1376	3/23/70	TFFL	Summary of Minutes of Meeting on 3/17/70 - TFFL Core Periphery Tests
TE-1417	5/7/70	TFFL	Core Periphery Meeting
TE-1421	5/11/70	TFFL	Investigation of TFFL Z-liner Fabrication
TE-1423	5/14/70	TFFL	211 Disassembly
TE-1425	5/18/70	TFFL	Post Test Inspection of 64DT-211

* TFFL- Thermal & Fluid Flow Laboratory, TD- Thermal Design, RD- Reactor Design.

<u>Document No.</u>	<u>Date</u>	<u>*By Dept.</u>	<u>Subject</u>
RD-1159	8/27/68	RD	High Expansion TFL-2a Corrosion Tests
NPE:HNH:1141	2/2/70	NPE	Constraints on Testing of 64DT-211 Core Periphery Corrosion Test
None	4/29/70	DE	64DT-211 Core Periphery Corrosion Test
None	5/19/70	TD & RD	Proposed Procedure for Sectioning of the 64DT-211 Periphery Test Fixture
TD-70-172	7/20/70	TD	Outline for Data Item T-119 for Development Tests 64DT-212 and 64DT-211

* TFFL-Thermal & Fluid Flow Laboratory, RD-Reactor Design, TD-Thermal Design, NPE-
NERVA Project Engineering

3.0 DESCRIPTION OF TEST MODEL

(CRD) The 64DT-211 Core Periphery Test Model was the third assembly of an R-1 Cold Buffer Type Wrapper Periphery to be tested in TFFL. The model features a multiple layer Z-liner wrapper made entirely from thermalized rerolled pyrofoil. In addition, the simulated elements and core are made from SX-5 graphite which has a higher CTE than previous cores.

The SX-5 graphite closely simulates the growth characteristics of the proposed high expansion R-1 fuel.

(U) The basic model is 6 inches in diameter, 47 inches long, and contains: (a) a 3.5 inch diameter core assembly; (b) a simulated graphite unimpregnated reflector; and (c) a modified NRX-A2 type lateral support and seal system. Assembly details of the model are described by Drawing No. 711J745.

(CRD) The model core assembly consists of an NbC coated inner core, uncoated simulated elements, and uncoated cold periphery type spacer assemblies which included 0.125 inch thick insulating tile. The wrapper which is sandwiched between the elements and insulating tile is the primary hardware being tested. The wrapper is nominally 180 mils thick and consists of 34 layers of Z-liners. Each layer contains 12 Z-liners which are preformed from full length pyrofoil strips 1-1/8 inch wide and a nominal thickness of .005 inches. Each Z-liner is approximately 2 simulated fuel element flats wide by 47 inches long. The initial liners are joined to the mating element periphery surfaces with a temporary bonding agent (Petrolatum PDS 30189-1) which is used for assembly purposes only. Subsequent Z-liners are similarly joined to previously positioned consecutive layers to achieve a total nominal wrapper thickness including petrolatum of 180 mils. The numerous small width Z-liners are sized from layer-to-layer to provide a uniform distribution of butt joints, and to maintain a controlled butt edge-to-edge clearance within 0 to 30 mils. Within each full length axial gap, a local constriction of 10 mils or less must exist.

(CRD) The wrapper was made from thermalized rerolled pyrofoil which was procured on ERCO 16728 per PDS 30141-1.

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A summary of the Mechanical Design features of the model is shown in Table 3-1. Figure 3-1 shows a cross-sectional illustration of the model. Figure 3-2 shows a cutaway view of the test article which includes the model installed within the FS-1 furnace.

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TABLE 3-1

SUMMARY OF MECHANICAL DESIGN FEATURES OF TEST MODEL
DEFINED SCOPE OF TEST 64DT-211
(GENERAL ASSEMBLY DRAWING No. 711J745)

COMPONENT	MATERIAL	DESCRIPTION
Heater	Graphite-Commercial Grade Graphitite "G"	NT-701509-101, Tapered solid rod, uncoated.
Inner Core	Graphite-Commercial Grade SX-5	WT-701736-408, NbC coated.
Simulated Element	Graphite-Commercial Grade SX-5	WT-701736-Sheets 3 and 14, full length uncoated, with and without instrumen- tation holes.
Wrapper (34 Layers)	Pyrofoil-PDS-30141-1 (Thermalized Rerolled)	100E078 - full length Z-liners .004 to .006 thick fabricated by TFFL/RA personnel.
Insulating Tile	Graphite - Pyrolytic PDS-30016-4	WT-701736-501, full length .125 inch thick, cool periphery type.
Spacer (Filler Strip)	Graphite-PDS-30020-2	WT-701736, Sheets 2 and 14, full length cool periphery type, with and without instrumentation holes.
Seal System *	Graphite-Commercial Grade Graphitite "G"	WT-701736, Sheet 18. 17 rows of seal segments. Each row having 12 flow holes. Rows 1 - 6, 0.104 dia. Rows 7 - 11, .063 dia. Rows 12 - 16, .055 dia. Row 17, .046 dia.
Inner Reflector *	Graphite-Commercial Grade, PO-3	Non-impregnated full length one piece construction with access holes for external plunger spring loading.
Lateral Support System	Inconel Springs	Spring/Plunger/Spacer/Plug Loading Hardware.

* Used in 64DT-212 Test Model.

Figure 3-1: Cross-Section of 64DT-211 Test Assembly

Figure 3-2: 64DT-211 Test Assembly Installed in Furnace

4.0 SUMMARY OF TESTS

4.1 NARRATIVE

(U) The 64DT-211 Core Periphery test configuration was designed, assembled, and tested to qualitatively evaluate the corrosion behavior of the outside layer of a thermalized rerolled pyrofoil wrapper design at representative R-1 wrapper temperature conditions. The primary purpose of the test was to subject the wrapper to a hydrogen pressure flow environment for eight cycles for a total steady-state test time of 80 minutes at outer a maximum outer layer temperature of 2500°R and to strains equivalent to the reactor wrapper O. D. The objective of the test was to obtain qualitative data of the pyrofoil wrapper corrosion resistance capability in order to confirm design assumptions not obtainable through analysis. To fulfill the requirements defined in TIS-DT-051.2B, three test phases were conducted. Phase I was an ambient temperature hydrogen flow test. Phase II was an intermediate power test. Phase III was a full power test to fulfill the requirements of the primary test objective.

(U) The purpose of Phase I test was to obtain the ambient pressure drop of the model at various flow conditions in order to define the impedance characteristics of the model under normal modes of test operation.

(CRD) The purpose of the Phase II Intermediate Power Test was to provide a controlled start-up temperature-time rate and hold in order to provide sufficient time to permit outgassing of the petrolatum over the aft end regions of the wrapper. From the result of the EML tests (WANL-TME-2736) on the radial growth of pyrofoil wrapper assembled with petrolatum and subjected to a 40°R/sec temperature ramp, there was some risk in the testing of 64DT-211 as originally planned. The risk involved possible increase in the wrapper thickness, due to petrolatum outgassing and possible failure of the plunger spring caps and seal segments as previously observed in 64DT-031 Core Periphery Test. To minimize the risk of this potential failure, the Phase II test plan was devised to minimize the rate of petrolatum outgassing.

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The purpose of the Phase III test was to temperature cycle the wrapper 8 times at full outer layer wrapper steady state temperature conditions (2500°R) for a total nominal test duration of 80 minutes.

4.2 Phase III Test Conditions

For the full power test the following general operating procedure was followed. Initiation of flow and pressurization requirements for the experiments was established per the instructions defined in TIS-DT-051.2. Ambient temperature hydrogen gas was directed to flow through the interstices of the model. In addition, helium flow was controlled through the heater cavity and furnace atmosphere plenums while hydrogen coolant flow was maintained in the exhaust system.

Induced flow conditions through the primary systems were established at the following flow rates.

Hydrogen Model Flow	.005 lb/sec
Helium Heater Flow	.0005 lb/sec
Helium Atmosphere Flow	.003 lb/sec
Hydrogen Coolant Flow	.005 lb/sec

Pressurization and depressurization of the system was accomplished at a rate no greater than 50 psi/min. The back pressure was controlled at a constant 436 ± 5 psig pressure level throughout the flow test. During pressurization and depressurization of the system, the model inlet to furnace atmosphere and the model inlet to heater cavity pressure differential were controlled to maintain a 1 ± 1 psi. and 5 ± 5 psi. difference respectively.

After three (3) minutes of steady-state flow stabilization at ambient temperature operating conditions, the power was ramped to the intermediate power load specified at a rate consistent with the specified nominal heatup rate of $10^{\circ}\text{R}/\text{min}$. The rate was determined from the rate of change of temperature indication of a W/W 26% Re thermocouple in the simulated element located at Station 38 and was established utilizing voltage step change

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control of the heater. After the required temperature level was reached the power level was maintained for one (1) hour to meet the specified temperature condition of 2000°R at element Station 38.

After (60) minutes at the Phase II intermediate power hold conditions were completed, additional power was supplied to the heater and adjusted to the nominal operating level prescribed for the Phase III full power test. Power up and down ramp rates were limited to 10 KW per step change at 5 second intervals until specified power levels were reached. The temperature ramp of nominal $10^{\circ}\text{R}/\text{min.}$ used for the intermediate power test startup did not apply for the full power test. The Phase III heated hydrogen cycle tests were controlled utilizing the W/W 26% Re thermocouple at Station 38 and/or Station 26 inches located in the simulated elements and chromel/alumel thermocouples located at the 36.0 station in the filler strips. While maintaining a constant back pressure of 436 psig, at constant flow conditions, the power level was adjusted to maintain, within practical test limitations, the 3265°R temperature prescribed for the simulated element at Station 38. Simulated element thermocouples at Station 38 inches were used as the primary control sensor with the thermocouples located at Station 26 inches being the back-up alternate.

The detailed procedural plans for the full power mode of operation are described in TIS-DT-51.2-B.

4.3 TEST RESULTS

Test results reported herein will be primarily directed to presenting the experimental results of the full power heated hydrogen corrosion flow test, Phase III. Detailed information of the ambient hydrogen flow tests and the intermediate power heated flow tests are reported in DRM 51384.

4.3.1 Recorded Data

Recorded data including detailed assembly and inspection measurements, photographic information, graphic presentation of pertinent test information, and time histories are reported

in DRM 51384. The test phases were conducted as specified. Typical information pertinent to the full power test presented herein include the following information:

Summary of test condition compared with specified conditions, Table 4-1.

Control temperature time history, Figure 4-1.

Model pressure drop time history, Figure 4-2.

Start of test and end of test component temperature distribution, Figures 4-3 and 4-4.

Axial seal cavity pressure distribution, Figure 4-5.

TABLE 4-1
COMPARISON BETWEEN SPECIFIED AND MEASURED OPERATING
CONDITIONS REQUIRED FOR THE 64DT-211 FULL POWER TEST

Operating Control Parameters	Specified	MEASURED							
		Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6	Cycle 7	Cycle 8
Model exit, pressure, psig	436	435	435	435	435	435	435	435	435
Model hydrogen flow, lb/sec.	.0276	.0278	.0276	.0277	.0278	.0279	.0274	.0275	.0280
Model inlet to helium atmosphere pressure differential, psi	1 ± 1	0	0	+0.2	+0.1	+0.9	+0.9	+0.2	+0.2
Heater cavity to model inlet pressure differential, psi	5 ± 5	+3.8	+3.8	+3.8	+3.8	+3.8	+4.3	+4.3	2.8
Exit nozzle hydrogen coolant flow lb/sec.	.10	.0827	.0832	.0676	.0618	.0476	.0444	.0443	.0372
** Element temp. sta. 38.0, °F	3265 ± 180°	3270	3270	3250	3305	3270	3260	3224	3224
** Element temp. sta. 26.0, °F	2240 ± 180°	2490	2393	2367	2402	2330	2290	2214	2271
** Filler Strip temp. sta. 36.0, °F	665	575	555	565	571	576	585	570	555
** Filler Strip temp. sta. 26.0, °F	490	413	399	404	404	404	413	404	390
<u>Monitoring Test Parameters (Reference Only)</u>									
Model pressure drop, psi	167	63	59.5	67	76	87	98	104	113
ΔT (Element - F.S.) sta. 38.0, °F	2600	2695	2715	2685	2734	2694	2675	2654	2669
ΔT (Element - F.S.) sta. 26.0, °F	1750	2077	1994	1963	1998	1926	1877	1810	1881
Power Requirements; (KW):									
Net Model:	70	---	---	---	---	---	---	---	---
Total Heater:	90	80.5	81.3	81.5	82.3	85.3	85.4	86.1	86.3
Reflector temp. (max.), °F	757	550	535	535	540	540	550	535	520
Exhaust gas temp. (max.), °F	400	300	292	310	318	362	373	342	385
Furnace atmosphere helium inlet flow, lb/sec.	.020	.0086	.0091	.0098	.0105	.0112	.0115	.0135	.0136
Heater cavity helium inlet flow, lb/sec.	.001 - .010	.0037	.0032	.0038	.0038	.0041	.0046	.0049	.0051
Current flow, amperes	1460	1400	1472	1468	1489	1489	1491	1503	1507
Potential drop, volts	62	57.5	55.3	55.3	55.3	57.3	57.3	57.3	57.3
Time to temp., minutes	8 - 12	10	8	8	8	6	6	6	6
Cumulative steady state test duration at 3265 ± 180°F, minutes	---	15.3	28.6	41.3	53.4	65.4	77.5	89.5	101.3
Cumulative total test time, minutes	---	26	50	74	98	118	140	160	180
Cycle time, minutes	---	26	24	24	24	20	22	20	20

** Test was controlled at the best matched element temperatures to maintain corresponding filler strip temperatures in order to meet the test objective of wrapper O.D. temperature of 2500°R for a total nominal duration of 80 minutes.

Figure 4-1: Phase III Model Temperature-Time History
 (Average Fuel Element Temperature)

6133398 48C

Figure 4-2: Phase III Model Pressure Drop Time History

Figure 4-3: Measured Axial Temperature Distribution in First Cycle

Figure 4-4: Measured Axial Temperature Distribution in Last (8th Cycle)

Figure 4-5. Measured Seal Cavity Pressure Distribution

4.3.2 Discussion of Data

4.3.2.1 Test Data

(U) The full power EP III test of eight high temperature cycles for a nominal steady state duration of 80 minutes was completed as planned. During the entire test a total time of 101.3 minutes was accumulated within the specified station 38 temperature control range of $3265 \pm 180^{\circ}\text{F}$. The total operating time for each cycle was 23 minutes including the startup and shutdown periods. Power generated by the heater varied from 80.5 KW at the start of the test to 86.3 KW at the end of the test.

(U) The 64DT-212 periphery test reported in WANL-TME-2735 was a similar test of this periphery concept with the pyrofoil wrapper thermalized as assembled in the model. This 64DT-211 test model pyrofoil wrapper was built from thermalized rerolled pyrofoil. A comparison of the operating conditions for these two tests is given in Table 4-2. It can be seen that the temperature conditions were more severe in the previously reported 212 test, however, the operating time for the "211" test was slightly longer.

4.3.2.2 Post Disassembly Observations

(CRD) The O.D. layer (layer 34) of the pyrofoil wrapper was free from hydrogen corrosion, with the exception of very localized spots of incipient corrosion. During the disassembly, local corrosion was first observed in the axial butt joint gaps between edges of the 5 mil pyrofoil Z lines of layer 33 (at approximately the 44 inch station). Generally, observations showed that the wrapper corrosion was traceable to areas where butt joint gaps existed. In Figure 4-6 through 4-18 post test examination photographs of the outer wrapper surface condition are shown for layers 22 through 34. Bonding of the layers at this point prevented further disassembly. Figure 4-19 shows the surface condition of the inner most layers which operated at the highest temperature.

(CRD) No measurable corrosion was observed on the filler strip or insulating tile surfaces which were outboard of the pyrofoil wrapper.

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TABLE 4-2
COMPARISON OF TEST RESULTS
BETWEEN 64DT-212 and 211

	<u>212</u>	<u>211</u>
Planned Test Duration	80 min, 8 cycles	80 min, 8 cycles
Actual Test Duration At Planned Temperature Control Limits	96 min, 8 cycles	101 min, 8 cycles
Planned Control Temperature (Sta. 38 Elements), °R	3850 $\pm$ 180	3725 $\pm$ 180
Actual Control Temperature (Sta. 38 Elements), °R	3850 Nominal	3725 Nominal
Maximum Temperature (Sta. 38 Elements), °R	4035	3787
Planned Outer Wrapper Temperature (Sta. 38), °R	2500	2500
Actual Outer Wrapper Temperature (Sta. 38), °R	2630	2500
Model Pressure Drop (psid)	100 - 200	60 - 120
Total Full Power Test Time	276 min.	176 min.

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TABLE 4-3
FUEL ELEMENT POST TEST EXAMINATION

E-1, ELEMENT,

Corrosion Starts: 24" Station

Corrosion Regions: Butt joints and across surface

Surface Patterns: Corrosion starts at Station 24" to 47" along the butt joints and across "A" face at Station 29", 33" to 36", 45" and 47". Plating occurs at Station 46.

		<u>Station, Inches</u>
*Minimum Operating Gap:	< 5 mils	26
*Maximum Operating Gap:	≈ 30 mils	46 1/2
Maximum Corrosion Depth:	5 mils	44
Maximum Corrosion Width:	180 mils	39 1/2

E-4, ELEMENT,

Corrosion Starts: 12" Station

Corrosion Regions: Butt joints and across "A" face

Surface Patterns: Corrosion starts at Station 12" to 41" along the butt joint. Across "A" face at stations 21", 23", 24 1/2", 26 1/2 29 1/2", and 33". Plating occurs at Station 28" to 38" and 45 1/4" to 46 1/4". Pieces of Z liner attached at 45 1/2" to 46 1/4" Station.

		<u>Station, Inches</u>
*Minimum Operating Gap:	< 5 mils	12
*Maximum Operating Gap:	≈ 20 mils	40 1/4
Maximum Corrosion Depth	4 mils	40 1/4
Maximum Corrosion Width:	320 mils	46 1/2

*Determined from surface light, refraction, and flow patterns
NOTE: "A" face corresponds to surfaces shown in Figure 4-21.

E-2, ELEMENT,

10" Station

Butt joints and across "A" surface

Corrosion starts at Station 10" to 47" along the butt joint and across "A" face at station 24" and continues to Station 46". Plating occurs at Station 26" to Station 46". Z liner attached from Station 46" to 47".

	<u>Station, Inches</u>
< 20 mils	10
≈ 30 mils	45 1/2
20 mils	29 1/2
320 mils	36 to 39

E-5, ELEMENT,

15" Station

Butt joints and across "A" face

Corrosion starts at Station 15" along the butt joints to Station 35". Starts again 36 1/2". Along butt joint to 47" Station. Z liner attached at 46 1/2" Station. Plating 40 1/4" to 40 3/4", 41 3/4" to 42 1/4", and 45 1/4" to 46 1/4".

	<u>Station, Inches</u>
< 5 mils	12
30 mils	45 1/2
7 mils	46 1/2
320 mils	46 1/4

E-3, ELEMENT,

12" Station

Butt joints and across "A" face

Corrosion starts at Station 12" to 47" along the butt joint. Across "A" face at Station 36" to 45". Plating exists at Station 45" to 46". Pieces of Z liner attached at Station 46 1/4".

	<u>Station, Inches</u>
< 5 mils	10
40 mils	37
8 mils	43
320 mils	41 to 45

E-6, ELEMENT,

24" Station

Butt joint and across "A" face

Corrosion starts at Station 24" and continues to 35" along butt joint. Starts again at 37" and runs to 47" along butt joint. Across "A" face at 45 1/2" to 47". Element damaged at tap location at 45 7/8" to 47" Station. Plating occurred from 40" to 46" Station and 28" Station.

	<u>Station, Inches</u>
< 5 mils	24
70 mils	43
7 mils	46
360 mils	46 1/2

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TABLE 4-3 (CONT'D)
FUEL ELEMENT POST TEST EXAMINATION

	<u>E-7, ELEMENT,</u>		<u>E-8, ELEMENT,</u>		<u>E-9, ELEMENT,</u>	
Corrosion Starts:	16" Station		18 1/2		19" Station	
Corrosion Regions:	Butt joint and across "A" face		Butt joints and across "A" face		Along butt joints and across "A" face	
Surface Patterns:	Corrosion starts at 16" Station to 33" Station along butt joints. Again at 34 1/2" Station to 44 1/2" Station from 45 1/2" to 47" Station along butt joints. Across "A" face at 26" to 35" Station and 46" to 47" Station. Plating from 28" to 39" Station and 44 1/2" to 46 1/2" Station.		Starts at 18 1/2" Station and runs to 47" Station along butt joint. Across "A" face 29" to 30", 32 1/2" to 33 3/4", 36" to 36 1/2", and 45 1/2" to 47" Station. Plating occurs at 44 1/2" to 45 1/2" Station. Cut marks seen in photos at 31", 35", 39", 41", and 44" Station come about when section of Z liners were removed.		Corrosion starts at Station 19" along butt joints. Across "A" face 32 1/2" to 33 1/2", and 46 1/2" to 47" Station. Plating 45" to 46 1/2" Station. Deposit at 45" Station.	
	<u>Station, Inches</u>		<u>Station, Inches</u>		<u>Station, Inches</u>	
*Minimum Operating Gap:	< 10 mils	16	< 5 mils	18 1/2	< 5 mils	24 1/2
*Maximum Operating Gap:	110 mils	35	20 mils	25	60 mils	36 1/2
Maximum Corrosion Depth:	2.5 mils	41 and 25	4 mils	29 1/2	2 mils	33
Maximum Corrosion Width:	320 mils	46 1/2	220 mils	36	160 mils	42
	<u>E-10, ELEMENT,</u>		<u>E-11, ELEMENT,</u>		<u>E-12, ELEMENT,</u>	
Corrosion Starts:	19" Station		11 1/2" Station		12" Station	
Corrosion Regions:	Along butt joints and "A" face		Along butt joints and across "A" face		Along butt joints and across "A" face	
Surface Patterns:	Corrosion starts at 19" Station along butt joints. Across "A" face 24 1/2" to 27", 29" to 30", 33" to 33 1/2", and 39" to 45" Station, 46 1/2" to 47" Station. Plating at 45 1/2" to 46 1/2" Station. Deposit at 46" to 46 1/2" Station.		Corrosion starts at Station 11 1/2" to 47" along butt joints. Across "A" face at 24" to 45" and 46 1/8" to 47" Station. Deposit from 45 1/4" to 46 3/4" Station. Z liner attached at 46 1/8" and 46 1/2" Station.		Corrosion starts at 12" Station to 16" Station and from 17" Station to 47" Station. A series of pit marks from 19 1/2" to 20 1/2" Station on "A" face. Across "A" face 30", 47" Station. Plating occurs from 45" to 46 1/2" and 46 3/4" to 47" Station. Z liner attached at 46 1/2" Station. Deposit at 46 1/4" to 47" Station.	
	<u>Station, Inches</u>		<u>Station, Inches</u>		<u>Station, Inches</u>	
*Minimum Operating Gap:	< 5 mils	30	< 5 mils	30 1/2	< 5 mils	27 1/2
*Maximum Operating Gap:	40 mils	38	80 mils	38	20 mils	25
Maximum Corrosion Depth:	7.5 mils	30	3 mils	35	26 mils	20
Maximum Corrosion Width:	320 mils	25	320 mils	46 1/2	320 mils	44

*Determined from surface light, refraction, and flow patterns

(CRD) Examination of the simulated fuel elements showed various degrees of corrosion, deposition, and plating. Figure 4-20 and 4-21 typically describes the element surface condition. Table 4-3 summarizes the condition of the peripheral elements.

(CRD) Wrapper corrosion in general was less severe than that observed in the 64DT-212 test. This is consistent with the higher operating temperature and larger pressure drop of the "212" test.

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Figure 4-6: Phase III Post Test Examination Photograph Showing the Outer Surface Condition of the Z-Liners from Layer 34

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MDT-211
PHASE III
POST TEST
6-8-70

LAYER NO. 33
OUTSIDE

Figure 4-7: Phase III Post Test Examination Photograph Showing the Outer Surface Condition of the Z-Liners from Layer 33

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Atomic Energy Act - 1954

Figure 4-8: Phase III Post Test Examination Photograph Showing the Outer Surface Condition of the Z-Liners from Layer 32

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Figure 4-9: Phase III Post Test Examination Photograph Showing the Outer Surface Condition of the Z-Liners from Layer 31

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Figure 4-10: Phase III Post Test Examination Photograph Showing the Outer Surface Condition of the Z-Liners from Layer 30

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64DT-211
PHASE III
POST TEST
6-8-70
LAYER NO. 29
OUTSIDE

Figure 4-11: Phase III Post Test Examination Photograph Showing the Outer Surface Condition of the Z-Liners from Layer 29

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Figure 4-12: Phase III Post Test Examination Photograph Showing the Outer Surface Condition of the Z-Liners from Layer 28

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Figure 4-13: Phase III Post Test Examination Photograph Showing the Outer Surface Condition of the Z-Liners from Layer 27

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Figure 4-14: Phase III Post Test Examination Photograph Showing the Outer Surface Condition of the Z-Liners from Layer 26

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4-25

Figure 4-15: Phase III Post Test Examination Photograph Showing the Outer Surface Condition of the Z-Liners from Layer 25

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Figure 4-16: Phase III Post Test Examination Photograph Showing the Outer Surface Condition of the Z-Liners from Layer 24

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Atomic Energy Act - 1954

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Figure 4-17: Phase III Post Test Examination Photograph Showing the Outer Surface Condition of the Z-Liners from Layer 23

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Figure 4-18: Phase III Post Test Examination Photograph Showing the Outer Surface Condition of the Z-Liners from Layer 22

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Figure 4-19: Phase III Post Test Examination Photograph Showing the Outer Surface Condition of the Z-Liners from Layer 1

"A" SURFACE

Figure 4-20: Post Test Examination Photographs of the Simulated Elements

"A" SURFACE

Figure 4-21: Post Test Examination Photographs of the Simulated Elements

5.0 ANALYSIS

5.1 STRUCTURAL ANALYSIS

5.1.1 Structural Analytical Model of Test Fixture

(U) The test fixture was modeled for structural analysis by dividing the heater rod, inner core, simulated fuel elements, wrapper, pyrotiles, filler strips and seal system into a series of concentric layers of a 30° sector as shown in Figure 5-1. This analytical model was used in the calculation of intercomponent operating gaps, radial expansion data and wrapper strains. The model was conservatively assumed to be free of external loads, with the inner core treated as a cylinder upon which free expansions of all other components were stacked, with the restriction that the wrapper had to stretch without slipping to fill the entire 30° arc.

5.1.2 Analytical Results and Comparison with Post-test Examination

5.1.2.1 Intercomponent Axial Flow Gaps

(U) Filler strip and tile gaps were calculated for the maximum operating temperature profile using the Structural Analytical Model. The results are shown in Figure 5-2 and represent the growth of the initial assembly gaps. The additional gap between fuel elements at operating conditions was assumed to be negligible compared to the assembly gaps. It should be noted that because the operating gaps are a function of temperature profiles and the temperature profiles are a function of gap distribution, the calculation of gaps and temperatures is an iterative process which requires several iterations for convergence. No measured operating gaps are available for comparison with calculated values, however, the calculated gaps are reflected in comparisons of calculated and measured temperature profiles and power levels.

5.1.2.2 Radial Expansion at Seal Segment Interface

(CRD) The maximum radial growth of the assembly at the seal segment interface was also calculated using the Structural Analytical Model. Wrapper expansion due to decompression was added to the free thermal expansion of the assembly to obtain the total growth at the seal segment interface. The expansion of the wrapper due to decompression at a rate of 50 psi/min was obtained by linear extrapolation of 64DT-317 Test Results,

Figure 5-1: Structural Analytical Model

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Figure 5-2: Intercomponent Gaps

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with compaction due to bundling conservatively neglected. The results are shown in Figure 5-3 with the maximum growth being approximately 25 mils. Because this calculated growth leaves only a nominal 5 mils of margin before the lateral support springs bottom, an intermediate power (slow ramp and hold) run was added to the test plan so that the additional wrapper growth component due to petrolatum outgassing would not occur simultaneously with the maximum thermal growth of the assembly. No problems with lateral support springs bottoming out were observed, however post-test diameter measurements indicate a net radial growth of approximately 13 mils on the radius at the forward end where the support spring clearance is nominally 15 mils. The net radial change (difference between post-test and pre-test diameter measurements) is shown in Figure 5-4.

5.1.2.3 Wrapper Ratcheting

(CRD) Post test inspection revealed no gross cumulative cyclic motion of the wrapper. However, one Z liner which was in the wrapper layer adjacent to the fuel was observed to be displaced approximately 1.5 inches out the forward end of the assembly. This one liner had a tear at approximately station 6, which enabled the forward 6 inches to be "pumped" out the forward end during several cycles of heating and cooling.

5.1.2.4 Wrapper Strain Analysis

(CRD) Wrapper strains were calculated at maximum operating temperatures based on the Structural Analytical Model and are shown in Figure 5-5. These calculated wrapper strains are higher than the thermalized pyrofoil strain capability based on data available at the time of the testing and caused concern that the wrapper might tear. However, it was pointed out that a continuous wrapper was assumed in the calculation of these strains and relief due to slipping would probably reduce them to an acceptable level. No local wrapper tears other than as described in the preceding paragraph were observed during post test inspection. The CTE for the SX-5 core is approximately 40% higher than the value for graphite "G" (used for the "212" core assembly). The test observations support the conclusion that the wrapper can accommodate the growth of high expansion fuel.

Figure 5-3: Radial Expansion at Seal Segment

Figure 5-4: Difference Between Post-test and Pre-test Diameter Measurements

Figure 5-5: Wrapper Strain

5.2 THERMAL AND FLUID FLOW ANALYSIS

5.2.1 Thermal and Fluid Flow Model

All thermal and hydraulic calculations were made with the TRACK II computer program described in WANL-TME-2697. A conduction model of the 211 core periphery test configuration was made by dividing the heater rod, the inner core, the simulated fuel elements, the pyrofoil wrapper, the filler strips, the inner reflector, and the shroud into appropriate nodes for a 30° sector. A hydraulic model was developed for the gap between the tile and filler strips, the seal coolant channel holes, and the seal plena. A total of 11 axial stations were specified in the model to describe the thermal and hydraulic conditions at stations: 1.0, 3.8, 9.4, 15.1, 17.9, 26.3, 37.4, 43.2, and 46 inches. Figure 5-6 illustrates the component parts of the thermal and hydraulic model.

The method of analyzing this test was identical to that reported in the 64DT-212 Data End Item report. The test hardware and geometry are identical to the 212 tests with the following exceptions: SX5 graphite is used in place of graphite G for the inner core and simulated fuel; the filler strip gaps were modified to reflect the expansion properties of SX5 material, and the pyrofoil wrapper is rerolled thermalized instead of thermalized hot filler strip gaps presented in Figure 5-2 that were input to the analytical model.

The analysis was performed by specifying the power into the test model, the measured flow rate, and the model inlet temperature. No flow paths other than those communicating with the seal chamber plena were used in the analysis. Therefore, the flow through fuel element interelement gaps, the butt joint gaps between wrapper layers and the wrapper fuel element interface gaps was not included in the analysis. The specified power in the analysis includes only that power associated with the fluid heat pickup.

5.2.2 Comparison of Prediction and Results

Using the predicted temperatures and pressures as being representative of the steady state operation, a comparison of measured and calculated data was made. Of prime

Figure 5-6: Components of 64DT-212 Core Periphery Model

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concern was the thermal performance of the pyrofoil wrapper at full power. Figure 5-1 indicates that the test objective of an O.D. wrapper temperature of 2500°R was achieved. Based on the observed station 38 material temperature which was monitored during the test, and the constant power-flow input to the model, it was concluded that this test objective was achieved at steady state for all eight cycles.

Simulated fuel element and filler strip material temperatures were recorded at stations 2.0, 10.0, 18.0, 26.0, 36.0, and 44.0 inches. Figures 5-7 and 5-8 present a comparison between the measured values and the calculated values both in the simulated fuel and the filler strips for the full power 70 KW and the part power 40 KW runs. The calculated temperature of the wrapper O.D. is also indicated relative to the fuel element temperature which was the controlling temperature made during the test. The favorable agreement between the measured and calculated temperatures confirms that the wrapper O.D. achieved the test objective based on the assumed nominal material thermal conductivities.

It should be noted that the uncertainty on the measurements, i. e., thermocouple error, and data acquisition error, was estimated by the Thermal and Fluid Flow Laboratory to be approximately $\pm 60^{\circ}\text{R}$. An additional affect on temperature at the wrapper tile interface results from the uncertainty of the thermal conductivity property data. It was demonstrated upon performing the calculations at a 1σ level that the variance on the nominal wrapper O.D. temperature could be $+82^{\circ}$ to -98° .

Figure 5-9 presents a comparison of the normalized calculated and measured seal chamber pressure distributions. The measured pressure drop increased from 60 psid to 120 psid as the full power test progressed, while the calculated pressure drop was 170 psid. The measured pressure distributions are somewhat lower than calculated, yet fairly representative of the shape of the calculated distribution. The gradual increase in pressure drop from the first cycle to the eighth cycle at constant power and flow has been attributed to a shifting

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Figure 5-7: TFL 211 Core Periphery Test, Comparison of Measured and Calculated Material Temperature Distributions for Full Power Condition

Figure 5-8: TFL 211 Core Periphery Test, Comparison of Measured and Calculated Material Temperature Distributions for Part Power Conditions

Figure 5-9: Normalized Full Power Seal Chamber Pressure Distributions

in components during cyclic operation.

(U) It was concluded from the post-test comparisons that (1) an O.D. wrapper temperature of 2500°R was achieved in this test for the full power run; (2) To achieve the conditions given in (1) the specified power level was 70 KW, the model flow rate was 0.0276 lb/sec and the model inlet temperature 515°R ; (3) the measured pressure drop varied from 60 psi to 120 psi. This measurement was considerably lower than the calculated value, 170 psi. The history of this test has always shown discrepancies between measured and calculated pressure drops. This difference can be partially attributed to flow through the simulated fuel elements and wrapper which was not considered in the analysis; (4) specifying the test flow rate and the power into the model, the calculated component internal temperatures were in good agreement with the measurements; (5) The calculated normalized seal chamber pressure distribution was higher than the measurements.

5.2.3 Permeable Flow Effects

(U) The full power/flow test (Phase III) was run with the heater cavity helium pressure maintained at 5 ± 5 psi higher than the GH_2 inlet pressure. This operating plan was adopted to prevent porous flow of H_2 into the heater cavity. This section examines permeable flow effects through the core and its relationship to the measured helium flow and to core bundling.

(CRD) The measured permeable flow data for the "211" core are reported and discussed in DRM 52576 and DRM 51369. The measured "211" core permeability was a factor of approximately 20 greater than the measured "212" inner core permeability (reported in WANL-TME-2735). The measured data were obtained from a bench test assembly at ambient conditions on the bare SX-5 inner core. The method of analysis followed is outlined in WANL-TME-2735. Figure 5-10 shows the comparison between the calculated He porous flow and the estimated core flow for the "211" test fixture under ambient test conditions. The estimated core flow was obtained by subtracting the measured chuck leakage and metering plug leakage from the total measured helium flow. The analysis and Figure 5-10 lead to the conclusion that the interelement pressure distribution must be close to the LSS pressure distribution to explain the measured He flow. This conclusion is not, however, compatible with the expected pressure profile based on the calculated interelement gaps and axial temperature distribution.

5.3 CORROSION ANALYSIS

5.3.1 Analytical Models

(CRD) Calculations presented in this section were determined by two methods. First, calculations were performed using the ICAP computer program (WANL-TME-2735). Calculations were performed using 10X the nominal reaction rate constants. The nominal reaction rate data are reported in TME-2677, Section A-4.0.2.1. The rationale for using 10X the nominal reaction rate constants was arrived at from the post test evaluation of the "212" test.

Comparison of the measured and calculated pyrofoil wrapper corrosion in the "212" periphery

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Figure 5-10: Comparison of Calculated and Measured Helium Porous Flow Through Test Fixture

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test showed that the fundamental hydrogen corrosion of that material must be at least a factor of 10 higher than that determined from the earlier pyrofoil experiments reported in TME-2677 and DRM 1067.

(CRD) The second calculational method for corrosion of pyrofoil was based on the assumption that there was sufficient hydrogen flow available to allow a forward corrosion reaction only. That is, the corrosion is limited by the reaction rate constants for pyrofoil rather than the amount of hydrogen available. This analysis is also based on 10X the previously used nominal reaction rate constants.

5.3.2 Post Test Evaluation

5.3.2.1 Corrosion Equivalent Test Time

(CRD) The 180 minute full power test consisted of 8 cycles which operated at a peak power, pressure, and temperature condition (avg. value at station 36 I.D. = 3740°R) for approximately 10 minutes per cycle. For the balance of the test, during startups and shutdowns, the fixture operated at lower temperatures and pressures. For the "211" test fixture the equivalent test time was defined as the time which would produce the same corrosion damage as a test run at a constant pressure of 40 atmospheres and a wrapper I. D. temperature of 3740°R . The calculated equivalent test time is 93 minutes. The comparable value for the "212" fixture was 115 minutes at a wrapper I. D. temperature of 3900°R . The assumption implicit in the value of this concept is that the other layers at their respective peak temperatures also have nearly the same equivalent test time. No transient measurements, except for the average fuel element temperature, exist to verify the validity of this assumption.

5.3.2.2 Corrosion Analysis and Comparison to Test Observations

(CRD) Section 4 gives a selected photographic survey of the outer wrapper layers. Bonding which occurred within layers 1-22 prevented further disassembly of the wrapper. An examination of the pyrofoil wrapper led to the conclusion that the "211" core showed much the same pattern of corrosion as the "212" core, with corrosion appearing largely to

originate from GH_2 leakage in the butt joint gaps between adjacent pyrofoil wrapper layers. Consequently, computations were based on that fact. The assumed butt joint geometry is a slot 5 mils thick (corresponding to the pyrofoil nominal thickness) by 10 mils, extending the entire 47 inches length of the wrapper. Figures 5-11 and 5-12 present the ICAP calculations for a model pressure drop of 60 psi and 120 psi respectively. This represents the extremes of the variation model pressure drop measured during the full power test phase. These two figures show a maximum regression depth perpendicular to the basal planes of 11 mils. Employing the wrapper temperature profiles shown in Figure 5-7, computations (ICAP) were made of regression depth perpendicular to the basal plane for the maximum (I. D.), average and minimum (O.D.) wrapper temperature profiles. Figure 5-13 shows the maximum regression depth extracted from those analyses plotted versus layer number. The ICAP calculation is based on a model $\Delta P = 120$ psi which tends to overestimate corrosion damage. Presented in the same figure is the regression depth versus layer number relationship calculated for a forward reaction only. Experimental data indicating whether or not corrosion originating in a given butt joint resulted in corrosion through an adjacent layer are also indicated on this plot. This comparison indicates that observed corrosion of the outermost layers cannot be explained by any of the postulated corrosion models.

(CRD) Figure 5-14 shows the measured data for the extreme aft and forward stations at which corrosion damage penetrated a given layer. These data were taken from an examination of the pyrofoil segments adjacent to fuel element pieces E-9 and E-10. As previously explained, data are reported for layers 22-34 only because of bonding interior to layers 1-22. Observable corrosion damage occurred on all layers.

5.3.2.3 Comparison Between Observed Corrosion Damages in "211" and "212" Tests

(CRD) The ICAP model, using 10X nominal rate constants, predicts complete corrosion damage would extend from stations 30-40 (Reference Figures 5-11 and 5-12). The bulk of the measured data goes from station 29 to 45 which agrees with the 10X nominal rate constants. Figure 5-13 shows that the predicted corrosion damage would only extend through to layer 23. This substantiates the original conclusion drawn from the "212" test that the

Figure 5-11: Calculated Corrosion Depth Profile (Model $\Delta P = 60$ psi.)

W58831-1

Figure 5-12: Calculated Corrosion Depth Profile (Model $\Delta P = 120$ psi.)

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Figure 5-13: Comparison of Measured Wrapper Corrosion Depth Perpendicular to Basal Plane with Various Analytical Calculations.

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Figure 5-14: Axial Limits for Total Wrapper Corrosion

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observed corrosion of the outermost layers of the pyrofoil wrapper cannot be explained by any of the postulated corrosion models, even with increased corrosion rate constants.

(CRD) The post test examination of the "211" pyrofoil wrapper showed less severe corrosion damage than the "212" wrapper. This difference could be in part due to four factors:

- (U) 1. The "212" test in general ran at both a higher I.D. temperature (3900°R versus 3740°R) and a higher O.D. temperature (2633°R versus 2500°R) than the "211" test.
- (CRD) 2. The test time for the "212" test was slightly longer than the "211" total test time.
- (U) 3. The "212" model pressure drop varied from approximately 100 psi to 200 psi during the conduct of the full power test. The "211" model pressure drop varied from 60 psi to 120 psi indicating a lower wrapper interstitial flow, assuming similar flow path geometry for the "211" and "212" tests.
- (CRD) 4. The "212" pyrofoil wrapper thermalized on the test fixture in place. The material used for the "211" test assembly was, on the other hand, installed already thermalized and rerolled. The rerolling gives a higher density material.

(CRD) The above factors make it impossible to reach any positive conclusions with respect to the difference in corrosion performance between thermalized pyrofoil (in-situ) and thermalized rerolled pyrofoil. The latter process corresponded to the specification for the R-1 grade material (PDS 30141-1).

(CRD) Table 5-1 summarizes a comparison of the observed corrosion pattern in one selected area of the pyrofoil wrapper for the "211" and "212" assemblies. These observations were made on pyrofoil strips adjacent to fuel elements E-9 and E-10. The comparison was made on selected layers of the 211 and 212 wrapper which operated at nearly the same temperature. This comparison shows that the "212" pyrofoil wrapper experienced more severe corrosion damage than the "211" wrapper. However, nothing in this comparison suggests that these differences in corrosion behavior can be attributed to the difference between thermalized pyrofoil and thermalized rerolled pyrofoil.

TABLE 5-1
COMPARISON OF CORROSION DAMAGE BETWEEN
the 64DT-211 and 64DT-212 PERIPHERY MODELS

Wrapper Layers With Similar Temperatures		Comments
64DT-211 Layer No.	64DT-212 Layer No.	
22 & 23	21	"211" and "212" damage similar
24	22	no corrosion on "212", spotty corrosion on "211" wrapper
25 & 26	23	"212" corrosion appears in more localized region, "211" corrosion aft of "212" corrosion
27	24	large area corroded on "212", slight corrosion on "211"
28	25	large area corroded on "212", slight corrosion on "211"
29	26	Larger area corroded on "212" than "211", damage on "211" aft of "212"
30	27	significant corrosion on both "211" and "212", corrosion damage on "211" covers larger axial distance

Notes: (1) "212" wrappers layers 1-23 thermalized in place, not rerolled, layers 24-27 rerolled, thermalized foil
(2) "211" wrapper rerolled thermalized pyrofoil

6.0 CONCLUSIONS

6.1 SPECIFICATION AND TIS REQUIREMENTS

(U) Table 6-1 relates the test results to the applicable specification and TIS requirements.

TABLE 6-1
SUMMARY OF SPECIFICATION AND TIS REQUIREMENTS

{CRD}	Specification/TIS	Paragraph	Requirement	Test Conclusion
	ECC 677564	3.1.1.1.2.3.1	Impede Radial Leakage	Test indicated no radial leakage occurred through wrapper either as a result of porous flow or direct radial leakage.
	ECC 677564	3.1.1.1.2.3.2	Impede Axial Flow	Test fixture demonstrated inadequate axial flow impedance on the basis of measured corrosion damage.
	ECC 677564	3.1.1.1.2.4	Provide Thermal Impedance	Test provided good correlation with predicted radial temperature gradient.
	ECC 677564	3.1.2.3	Useful Operating Life- 600 Minutes, 60 Cycles Max.	Not demonstrated in Test.
	TIS-2	1.1	Indicate Wrapper o.d. Cyclic Corrosion Resistance Capability	Wrapper o.d. corrosion resistance appears compatible with R-1 temperature conditions.

6.2 TEST CONCLUSIONS

(CRD) On the basis of the preceding discussion, the following conclusions have been reached.

(CRD) 1. The wrapper design concept (full length pyrofoil wrapper) tested does not have the requisite 10 hour lifetime.

(CRD) 2. Large axial leakage flow occurred through the wrapper as evidenced by wrapper corrosion damage.

(CRD) 3. From an inspection of the wrapper O. D., it was observed that no measurable corrosion damage occurred in regions exposed to temperatures less than approximately 2400°R.

(CRD) 4. The observed corrosion damage was not analytically predicted with the present modelling of the corrosion phenomenon. The analytical model did, however, predict plating out and bonding within stations 30-45, consistent with test observations.

(CRD) 5. No significant corrosion occurred on the radial faces of the simulated fuel elements suggesting the presence of helium in the interelement gaps.

(CRD) 6. The calculated interelement gap pressure distribution is in question because of uncertainty in the gap size and core permeability.

(U) 7. Differences between the calculated model pressure drop and the measured value can be partially explained by leakage flow through the wrapper. The normalized measured pressure distribution in the LSS was lower than with the predicted normalized shape.

(U) 8. Good agreement was realized between the predicted and measured temperature profiles in the simulated fuel elements and filler strips.

(CRD) 9. Wrapper strain capability was demonstrated to be adequate. Slippage probably occurred between pyrofoil layers relieving wrapper strain. No wrapper tears were observed during post test inspection.

(CRD) 10. Racheting of the wrapper could be a potential problem for the R-1 con-

figuration. It is, however, difficult to quantitatively relate test results to the R-1 configuration in view of differences in support features between the test fixture and the R-1 assembly.

(CRD) 11. Radial expansion of the "211" core appeared to be compatible with the "211" lateral support system.

(CRD) 12. No readily apparent differences between the 64DT-211 and 64DT-212 test assemblies which suggest any difference between thermalized and thermalized - rerolled pyrofoil were evident. The "211" and "212" test fixtures exhibited the same basic corrosion pattern, although the "212" fixture suffered more severe damage.

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TITLE Core Periphery Model Test 64DT-211	
	DOCUMENT NO. WANL-TME-2742	DATE September, 1970
ABSTRACT The cyclic corrosion resistance capability of an R-1 type periphery featuring a multiple layer Z-liner thermalized rerolled pyrofoil wrapper was experimentally measured. The results obtained in this test are consistent with those obtained in the 64DT-212 test with the thermalized wrapper thermalized in-place. This test further substantiates the low probability for this full length wrapper concept achieving the R-1 ten hour lifetime requirement. Corrosion damage to the pyrofoil wrapper appears to originate in butt joints between adjacent Z-liners. (CRD)		
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