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TO

AEC-NASA SPACE NUCLEAR PROPULSION OFFICE

COMPARISON OF WANL AND LASL FUEL ELEMENT
HYDROGEN CORROSION TESTING (U)

NERVA PROGRAM

DECEMBER 1964

CONTRACT SNP-1

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TO

AEC-NASA SPACE NUCLEAR PROPULSION OFFICE
COMPARISON OF WANL AND LASL FUEL ELEMENT
HYDROGEN CORROSION TESTING (U)

ROCKET ENGINE OPERATIONS - NUCLEAR

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ABSTRACT

This report compares the hydrogen corrosion testing facilities at WANL and LASL in order to better understand the differences in test temperature profiles. It was prepared in response to SNPO-C letter RB:GAK dated 10 August 1964. Subject: "Differences in Maximum Internal Temperature of Fuel Elements During Corrosion Test. (U)"

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TABLE OF CONTENTS

	<u>Page</u>
I. Purpose	1
II. Facility and Operating Procedure Description	1
A. WANL	1
B. LASL	1
C. Major Differences in Facilities and Test Procedure	4
III. Temperature Profiles	5
IV. Conclusions	7
V. Recommendations	8
VI. References	9

LIST OF TABLES

	<u>Table No.</u>
Comparison of Corrosion Test Parameters	I

LIST OF FIGURES

	<u>Figure No.</u>
LASL 301 RPT and WANL IC Test	1
LASL 301 RPT and WANL IB Test	2
LASL 301 RPT and WANL 1A Test	3
LASL 301 RPT and LASL 321 RPT	4
LASL 321 RPT and WANL 1A Test	5

I. PURPOSE

The purpose of this report is to compare WANL and LASL single fuel element hydrogen corrosion testing facilities, test procedures and resultant fuel element axial and radial temperature profiles. The differences in facilities and procedures will be presented in an attempt to better understand the variation in temperature profiles. The information presented should allow better comparison of WANL and LASL single element corrosion test results with NRX-A2 and KIWI B4E reactor post mortem evaluation.

II. FACILITY AND OPERATING PROCEDURE DESCRIPTION

A. WANL

The WANL single element corrosion test loop consists of the furnace, connector and heat exchanger. The furnace and heat exchanger are mounted horizontally and in line. There is no provision for optical pyrometer temperature readings from the hot end face. Four sight ports are provided for optical pyrometer temperature readings. These ports are located approximately 3.5-, 14-, 36.5-, and 48-in. from the fuel element hot end.

A standard 52 in. length fuel element is used in all tests. The test element is carefully loaded into the furnace. The loading procedure includes the proper fitting of the graphite chucks to the fuel element. Approximately 1 3/4 in. of the fuel element is in the chuck at each end leaving a heated length of 48.5-in.

To start the test the system is purged with helium. Hydrogen at ambient temperature is then introduced into the system and brought up to the desired flow rate and element exit pressure. Electrical power from a 2.8 MW direct current power supply is applied in a series of step functions until the desired power level is reached. Optical pyrometer temperature readings, taken at the sight port 14-in. from the hot end are used to adjust power input, in order to maintain the desired surface temperature profile. After a specified time, normally 5 minutes, power is decreased in a series of step functions. The element is cooled with hydrogen then purged with helium and then nitrogen.

A detailed description of WANL's test facility and testing procedure is contained in References (1) and (2).

B. LASL

The LASL single element corrosion test loop as used for testing 301 core elements consisted of the furnace, 90° elbow connector and heat exchanger.

The connector is fitted with a sight port which allows optical pyrometer temperature readings to be taken directly on the hot end face. Five additional sight ports are provided for optical pyrometer temperature readings. These ports are located 3-, 14-, 24-, 35-, and 46-in. from the fuel element hot end.

The 52-in. length fuel element was cut to 43-in. for 301 core reactor profile tests (RPT). The fuel element when properly fitted into the chucks had a heated length of approximately 41-in.

On completion of the 301 core testing, a program was commenced to develop the RPT test for use in 321 core testing. Several changes have resulted from this program. A 52-in. length element is now used in all corrosion tests. The hot end chuck was changed to improve the reliability of the element support system. A much larger portion of the hot end of the element is contained in the new chuck, approximately 3.5-in., which results in a heated length of 46.25-in. The changed element support system results in the optical pyrometer sight ports being located approximately 5.5-, 16.5-, 27.5-, 38.5-, and 49.5-in. from the fuel element hot end. All pre-production 321 core testing is being done with 0.048-in. orifices in the center 7 holes and 0.032-in. orifices in the remaining outer holes.

The test procedure used in the 301 and 321 test is essentially the same. The system is purged with helium to start the test. Hydrogen at ambient temperature is then introduced into the system and brought up to the desired flow rate and element exit pressure. Electrical power from a submarine battery is applied slowly while taking continuous pyrometer readings. Temperature was controlled during 301 testing with readings taken 14-in. from the hot end. 321 tests are presently being controlled with temperature readings taken 5-in. from the hot end. Current is increased until the desired surface temperature is reached. After a specified time, either 5 or 10 minutes, power is decreased rapidly and the element cooled with reduced hydrogen flow then with a helium purge.

Only one test cycle was used during 301 testing. 73 tests were run for 5 minutes (RPT-5) and 155 tests were run for 10 minutes (RPT-10). 321 pre-production testing has consisted of two or more 10 minute cycles without removing the element from the furnace (RPT-2x10).

Several 321 pre-production fuel elements have been run four 10 minute test cycles (RPT 4x10) without failure.

Reactor profile life tests were also run during the 301 quality evaluation test series. In this test the fuel element is maintained at the standard temperature until failure. The time to failure is recorded.

It is felt at LASL that the 5 minute RPT test is not sufficiently sensitive to coating conditions.

A detailed description of LASL's test facility and testing procedure for 301 core tests is contained in References (3) and (4). Information concerning 321 core test development work has not, as yet, been published.

C. MAJOR DIFFERENCES IN FACILITIES AND TEST PROCEDURE

A comparison of corrosion test parameters is presented in Table I. It can be seen, from the above facility and operating procedure description and from Table I that the major differences which affect the radial and axial temperature profiles are:

- A. H_2 Flow Rate; WANL's hydrogen flow is 14% higher than LASL's.
- B. Power Generation; WANL's power input for the 1A test is 25% higher than 301 tests and 16.5% higher than 321 tests.
- C. Heated length of test element.
- D. Length of element in the hot end chuck.
- E. Use of orifices in the 321 core tests.

III. TEMPERATURE PROFILES

The temperature profile, devised by LASL for use in 301 core Reactor Profile Tests, was based on achieving a maximum material temperature of approximately 2475°C (4946°R). The resultant surface temperature to achieve this requirement was 2150°C (4361°R) at the sight port located 2-in. from the hot end of the element.

WANL established three surface temperature profiles, based on LASL experience, for use in evaluating the quality of production fuel elements. The standard surface test temperatures at 3.5 inches from the hot end are 4600°R (2282°C) Test 1A, 4460°R (2204°C) Test 1B, and 4320°R (2127°C) Test 1C. The resultant maximum material temperatures as calculated by WANL, Reference 5 and 6, are 5358°R (2703°C) Test 1A, 5145°R (2585°C) Test 1B, and 4952°R (2478°C) Test 1C.

Figures 1, 2, and 3 compare the LASL 301 RPT temperature profile with the WANL 1C, 1B and 1A temperature profiles.

From Figure 1 it can be seen that the maximum surface temperatures and maximum material temperatures for both tests are very nearly the same. The radial ΔT of 522°R (290°C) for the 1C test and 585°R (325°C) for the LASL test are within the expected experimental error for the methods used in determining the maximum material temperature. The difference in slope of the temperature profiles results in the LASL element having a higher temperature over more of its length. For a test of the same duration the LASL test should result in more corrosion and is therefore considered more severe.

Figure 2 compares the LASL 301 RPT with the WANL 1B test. The maximum material and maximum surface temperatures for the 1B test are approximately 198°R (110°C) higher than the LASL test. The radial ΔT is 593°R (329°C) for the 1B test as compared to the 585°R (325°C) for the LASL test. The difference in the slope of the axial temperature profiles makes direct comparison difficult, but it appears that the 1B test and the LASL 301 RPT test should result in approximately the same amount of corrosion for the same test time.

The WANL 1A test profile, Figure 3, is considerably more severe than the LASL test. The maximum surface temperature is 341°R (189°C) higher and the maximum material temperature is 412°R (229°C) higher. The 1A test radial ΔT is 656°R (364°C) as compared to 585°R (325°C) for the LASL test.

After completion of the 301 core quality evaluation test series, LASL commenced a corrosion test development program. The major objective of this program is to develop a corrosion test temperature profile that more nearly resembles the reactor temperature profile. This program is still in progress. The changes in test procedure, developed so far, are described in paragraph II B, above. Figure 4 compares the 301 RPT profile with the temperature profile being used to evaluate the 321 core pre-production fuel elements. The major difference in profiles is the reduction in radial temperature gradient resulting from the use of orifices. The maximum material temperature is approximately the same for each test, but the maximum surface temperature has been increased from 2150°C (4361°R) to 2250°C (4541°R).

The predicted Kiwi fuel element axial material temperature profile has been included in Figure 4 to show that the 321 RPT maximum material temperature profile is a much better simulation of expected reactor conditions than the 301 RPT or any of the WANL tests.

Figure 5 is a comparison of the LASL 321 core RPT and the WANL 1A test. The large difference in radial temperature gradient, 656°R (364°C) for the 1A test and 405°R (225°C) for the 321 RPT, indicates that the 1A test is more severe. The recent corrosion testing of WANL and Y-12 elements by LASL using their 321 RPT confirms this conclusion.

The calculated NRX fuel element axial temperature profile has been included in Figure 5 to emphasize the degree of simulation that LASL has obtained with minor test changes.

IV. CONCLUSIONS

A. There are several major differences between WANL and LASL hydrogen corrosion test facilities and operating procedures that make direct comparison of temperature profiles and test results very difficult. The most significant differences are:

1. Hydrogen flow rate
2. Internal power generation
3. Heated length of test element
4. Length of element in the hot end chuck
5. Use of orifices

B. The LASL 301 RPT is closely approximated by the WANL 1B test. Corrosion test results for similar test periods should be comparable.

C. The LASL 321 RPT presently being used for pre-production testing is more severe than WANL's 1B test, but not as severe as WANL's 1A test.

D. The LASL 321 RPT more nearly simulates the expected reactor fuel element axial temperature profile than any of the WANL test profiles.

E. The WANL 1A test temperature profile cannot be directly compared to any expected NRX-A reactor temperature profile.

V. RECOMMENDATIONS

A. The results of the LASL 321 Core corrosion test development program, together with the most recent information concerning the electrical resistivity of fuel elements, Reference (7), should be incorporated into WANL's hydrogen corrosion testing program for NRX-A4, in order to achieve a corrosion test temperature profile that more nearly simulates the expected NRX-A reactor axial temperature profile. The achievement of this goal would allow direct correlation of corrosion test duration with expected fuel element reactor test endurance.

B. The duration of the corrosion test should be based on the expected reactor test operating profile.

VI. REFERENCES

1. WANL TME 502, "High Temperature Testing of Pre-Production Fuel Elements", September 1963.
2. WANL Process Specification 294613 Revision No. 1 and No. 2, "Hydrogen Corrosion Testing".
3. "LASL Experiments on LASL-WANL Fuel Element Exchange Hydrogen Corrosion Testing Program". Symbol N-1-1105, November 1963.
4. "Hydrogen Corrosion Tests of KIWI B4E (301) and Coating Development Elements", Symbol N-1-1349, July 1964.
5. WANL TME 565, "Internal Temperatures of Fuel Elements During Environmental Testing", October 1963.
6. WANL TME 744, "Thermal Analysis of High Temperature Fuel Element Corrosion Tests", April 1964.
7. WANL TME 897, "Effect of Electrical Resistivity Variations on Maximum Material Temperatures during Environmental Testing of NRX-A2 Fuel Elements", September 1964.

TABLE I

COMPARISON OF CORROSION TEST PARAMETERS

<u>Parameter</u>	<u>Units</u>	<u>WANL</u>			<u>LASL 301</u>	<u>LASL 321</u>
1. H ₂ Flow Rate	lb/sec	.043			.039	.039
2. Inlet Pressure	psig	660			620	660
3. Exit Pressure	psig	560			560	550
4. H ₂ Inlet Temperature		ambient			ambient	ambient
5. Power	KW	$\frac{1A}{870}$	$\frac{1B}{784}$	$\frac{1C}{740}$	592	675
6. Duration of Startup	sec.	45-60			60-70	60-70
7. Duration of Shutdown	sec.	45-60			20-30	20-30
8. Test Duration	min.	5			5 or 10	Note 1
9. Length of Test Element	in.	52			43	52
10. Heated Length of Test Element	in.	48.5			41	46.25
11. Nominal Element Surface Temperature	°R	$\frac{1A}{4600}$ (2282)	$\frac{1B}{4460}$ (2204)	$\frac{1C}{4320}$ (2127)	4361 (2150)	4541 (2250)
12. Temperature Control Point	in. from H End	14			14	5.5
13. Orifices Used		no			no	yes Note 2

NOTES: 1. Two or more 10 minute test cycles without removing element from furnace.
 2. .048" orifices in the center 7 holes, .032" orifices in the remaining outer holes.

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FIGURE 1
LASL 301 RPT AND WANL 1C TEST (U)

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FIGURE 2
LASL 301 RPT AND WANL 1B TEST (U)

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FIGURE 3
LASL 301 RPT AND WANL 1A TEST (U)

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FIGURE 4

LASL 301 RPT AND LASL 321 RPT (U)

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FIGURE 5
LASL 321 RPT AND WANL 1A TEST (U)

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