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TECHNICAL DATA RECORD

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APPROVALS

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DEPT & GROUP NO.: 735-51

DATE: 11/23/63

GO NO: 7568

TITLE: SNAP 8 DRM-1 Fuel Element Test Monthly Report, October 1963

S/A NO: 2020

TWR: 54933

SECURITY CLASSIFICATION

(CHECK ONE BOX ONLY)

	AEC	DOD
UNCL.	☐	☐
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AUTHORIZED CLASSIFIER SIGNATURE: J G Sprauel DATE: 11-25-63

PROGRAM: SNAP 8

SUBACCOUNT TITLE: Fuel Element Performance Testing

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STATEMENT OF PROBLEM

To determine the performance of S8DRM-1 fuel elements under simulated flight reactor operating conditions.

ABSTRACT

The initial hydrogen loss rates of S8DRM-1 elements undergoing test are lower than corresponding rates of earlier SNAP 8 elements. The 1300°F pre thermal cycle permeation rates are lower than the rates predicted from the 1400°F acceptance permeation rates.

REFERENCE

1. Parker, T. G., Jr., "Developmental Tests on S8DRM-1 Fuel Elements", NR7568-06, July 7, 1963.

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FORM 701-C REV. 10-62

I. INTRODUCTION

The purpose of this developmental testing is to determine the performance of the S8DRM-1 fuel elements (normal uranium) under simulated flight reactor operating conditions. The elements are subjected to inputs simulating pre-launch check-out, launch, start-up, and operation. The effects of these tests are evaluated by measuring the hydrogen loss rate (permeation) before and after each input and during the endurance test. Testing is done in accordance with the referenced specification.

II. EQUIPMENT STATUS AND OPERATION

The same equipment used for SNAP 8 fuel element environmental* and qualification** testing will be used for testing the S8DRM-1 fuel elements.

III. TEST DESCRIPTION AND SEQUENCE

All fuel elements will be subjected to the following test inputs (cf. Figure 1):

1. Permeation Tests: All fuel elements will be subjected to permeation tests at 1300°F before and after each test input.

2. Thermal Soak: The fuel elements shall be heated at a rate 300°F/hr. to 1300°F. The elements will dwell for 10 hours at 1300°F and then be cooled to at least 400°F at a rate of 300°F/hr. The elements will receive three cycles of this input.

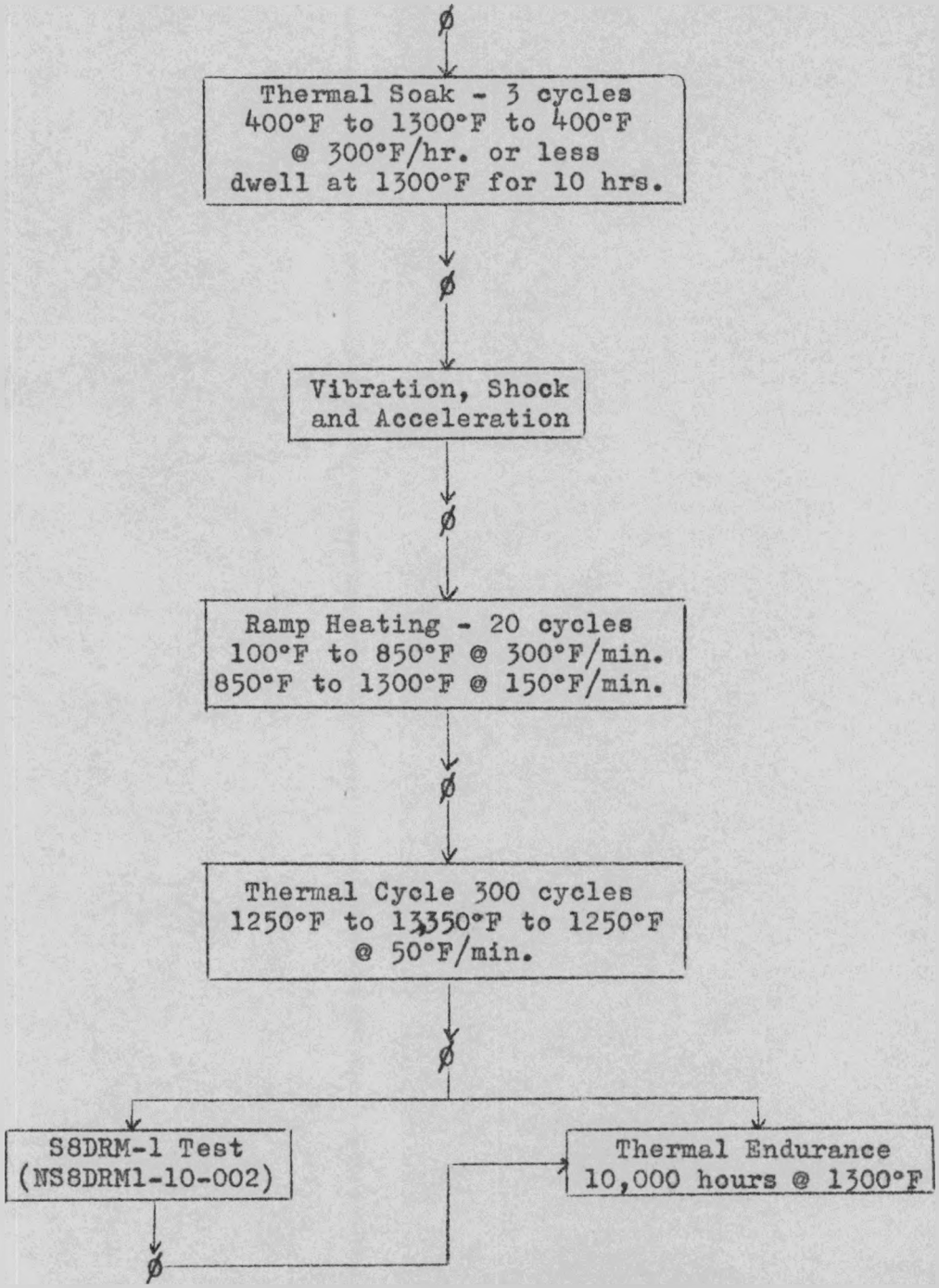
---

* Parker, T. G., Jr., "SNAP 8 Fuel Element Environmental Testing Status Report - October, 1963", NAA-SR-MEMO-9210, 11/12/63.

** Veeck, S. J., "SNAP 8 Fuel Element Qualification Program Status Report - September, 1963", NAA-SR-MEMO-9085, 10/14/63.

FIGURE 1

Developmental Testing Sequence



3. Vibration, Shock, and Acceleration: The fuel elements will be sent to Santa Susana for vibration, shock, and acceleration inputs shown in Table I.

4. Ramp Heating: The fuel elements will be heated from ambient temperature to 850°F at a rate of 300°F/min., and from 850°F to 1300°F at a rate of 150°F/min. The elements will be cooled at a rate not to exceed 50°F/min. The fuel elements will receive 20 cycles of this input.

5. Thermal Cycling: The fuel elements will be heated at a rate of 50°F/min. to 1350°F at which time the elements will be cycled from 1350°F to 1250°F three hundred times. The fuel elements will be cooled at a rate not to exceed 50°F/min.

6. S8DRM-1 Vibration, Shock, and Start-up Reliability: Twelve fuel elements which have been subjected to the test described above will be sent to D/727-72 for testing per NS8DRM-1-10-002. The twelve elements will be comprised of six of the -3* and six of the -4* design configuration. In the event that failures occur during the previous test, fuel elements will be supplied on the basis of availability.

7. Thermal Endurance Testing: The fuel elements which do not undergo test 6, and which have not failed** will be subjected to endurance testing at 1300°F. The elements which undergo test 6 will be subjected to endurance testing at 1300°F after completion of test 6, provided that the elements have not failed.

* Fuel elements of the -3 design have "collar-button" type hold-down devices to keep the fuel stationary in the cladding. Fuel elements of the -4 design do not have any hold-down device.

** Failure is defined as 2.5 times the acceptance rate at 1300°F.

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TABLE I

Launch Vibration, Shock and Acceleration Input Levels

VIBRATION

Axis	Magnitude	Frequency	Duration
Longitudinal	½ - inch double amplitude	5 - 12 cps	8 min.
Longitudinal	3.5 g	12 - 400 cps	8 min.
Longitudinal	7.5 g	400 - 3000 cps	8 min.
Lateral	½ - inch double amplitude	5 - 10 cps	8 min.
Lateral	2.5 g	10 - 250 cps	8 min.
Lateral	5.0 g	250 - 400 cps	8 min.
Lateral	7.5 g	400 - 3000 cps	8 min.

SHOCK

Axis	Magnitude	Description	Duration
Longitudinal	10 g	1 cycle ½ sine wave	6 milliseconds
Lateral	6 g	1 cycle ½ sine wave	12 milliseconds

ACCELERATION

Axis	Magnitude	Duration
Longitudinal	14 g	5 min.
Longitudinal (reverse)	4 g	5 min.
Lateral	6 g	5 min.

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8. Destructive Analysis: After completion of endurance testing, the elements will be subjected to destructive analysis.

IV. PROGRAM STATUS

There are to be approximately twenty-five fuel elements in this program. The twenty-five elements will consist of twelve of the -3 design and thirteen of the -4 design. Presently only twelve of the -4 design have been received for this program. These elements are now undergoing thermal soak.

V. RESULTS AND DISCUSSION

The data to date from testing the fuel elements currently in the program are shown in the Appendix. Average values are shown below:

	Average Hydrogen Permeation Rate, $\phi_{average}$, cc(STP)/hr.	Range of ϕ cc(STP)/hr.	Number of Elements
Acceptance at 1400°F	0.22	0.12 - 0.52	12
Pre-thermal soak at 1300°F	0.04	0.01 - 0.12	12

Corresponding values for S8ER type elements (normal uranium) undergoing environmental testing* are:

	Average Hydrogen Permeation Rate, $\phi_{average}$, cc(STP)/hr.	Range of ϕ cc(STP)/hr.	Number of Elements
Acceptance at 1400°F	0.58	0.07 - 1.18	20
Pre-thermal soak at 1300°F	0.28	0.01 - 0.62	20

* Parker, T. G., Jr., "SNAP 8 Fuel Element Environmental Testing Status Report - October, 1963", NAA-SR-MEMO-9210, 11/12/63.

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Corresponding values which are available for the fuel elements for the S8ER (enriched uranium) are:

	Average Hydrogen Permeation Rate, $\phi_{average}$, cc(STP)/hr.	Range of ϕ cc(STP)/hr.	Number of Elements
Acceptance at 1400°F	0.52	0.03 - 1.71	218

There are currently two methods for predicting the permeation rate of an element at one temperature when the rate is known at another temperature. The first method* is based on a statistical analysis of permeation tests of fuel elements numbered 1 - 77 of the S8ER design. The primary advantage of this approach is the ease of calculation. The second method** is an analytical approach, with the constants in the theoretical equations calculated from test data of all fuel elements in the S8ER core. The primary advantage of the analytical approach is that permeation rates can be logically predicted for nonisothermal conditions.

Using the 1400°F acceptance permeation rates, the corresponding 1300°F rates were calculated using both methods. The predicted rates and measured rates are compared in Table II. The agreement between the hydrogen permeation rates calculated by the two methods is good. However, the calculated values are biased when compared to the measured rates. The calculated rates are higher than the measured rates. The bias is attributed to one or more of the following causes:

1. The carbon, hydrogen, and uranium contents of the fuel in the DRM-1 fuel elements are different than in the S8ER fuel elements.

* Fitch, S. H., "Analysis of Permeation Data", NAA-SR-MEMO-7407, 5/21/62.

** Nathan, M. E., "Fuel Element Parametric Study Advanced SNAP 2 Reactor", NAA-SR-MEMO-8520, 5/27/63.

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TABLE II

Permeation Rates of S8DRM-1 Fuel Elements

Element No.	Acceptance ϕ_{1400} cc(STP)/hr.	Pre Thermal Soak ϕ_{1300} cc(STP)/hr.	Calculated ϕ_{1300} cc(STP)/hr. Fitch	Nathan
E-1023N-4	0.24	0.03	0.08	0.09
1028N	0.27	0.05	0.09	0.10
1041N	0.16	0.02	0.05	0.06
1044N	0.14	0.02	0.05	0.05
1063N	0.52	0.12	0.18	0.19
1064N	0.30	0.04	0.10	0.11
1066N	0.16	0.01	0.05	0.06
1070N	0.14	0.02	0.05	0.05
1089N	0.17	0.02	0.06	0.06
1119N	0.21	0.03	0.07	0.07
1129N	0.22	0.04	0.08	0.09
1133N	0.12	0.02	0.04	0.04

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2. The acceptance permeation rates of the DRM-1 fuel elements at 1400°F are significantly lower than the corresponding rates of the S8ER fuel elements. For example, the data used by Fitch showed no permeation rates lower than 0.5 cc(STP)/hr. at 1400°F, while only one DRM-1 element had a rate greater than 0.5 cc(STP)/hr. at 1400°F.

3. A new design of the final closure was incorporated into the DRM-1 fuel elements.

VI. CONCLUSIONS

The initial hydrogen loss rates of the S8DRM-1 elements undergoing test are lower than corresponding rates of earlier SNAP 8 elements.

The predicted 1300°F permeation rates based on 1400°F data, obtained using the correlations of Fitch and Nathan, are larger than the measured 1300°F permeation rates.

It appears that the change in the design between the DRM-1 and S8ER elements improved the elements such that the temperature-permeation relationships for S8ER fuel elements no longer hold. This will be checked further as additional data become available.

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APPENDIX

Test Data of S8DRM-1 Fuel Elements

NOTES: 1. N_H = Number of hydrogen atoms x 10^{-22}/cc of fuel.

w/o A = Weight percent of carbon additive in the fuel.

ϕ_{1400} = Fuel element hydrogen permeation cc(STP)/hr. @ 1400°F.

ϕ_{1300} = Fuel element hydrogen permeation cc(STP)/hr. @ 1300°F.

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TABLE I

UNCLASSIFIED

S8DRM-1 Developmental Test

FUEL ELEMENT NUMBER	E-1023[illegible]-4		
N_H	1.6		
w/o A	0.15		
$\emptyset_{1400}$ Acceptance	0.24		
$\emptyset_{1300}$ Pre Thermal Soak	0.03		

ENDURANCE TEST DATA

SYSTEM

FURNACE

RETORT

NOTES

ENDURANCE TEST DATA

DATE STARTED

PRETEST TOTAL ϕ =

HOURS	ϕ	HOURS	ϕ

DATE FINISHED

UNCLASSIFIED

[redacted]

[redacted]

TABLE II

UNCLASSIFIED

S8DRM-1 Developmental Test

FUEL ELEMENT NUMBER	E-1023M-4		
N_H	1.6		
w/o A	0.15		
$\emptyset_{1400}$ Acceptance	0.27		
$\emptyset_{1300}$ Pre Thermal Soak	0.05		

ENDURANCE TEST DATA			
DATE STARTED			
PRETEST TOTAL ϕ =			
HOURS	ϕ	HOURS	ϕ
DATE FINISHED			

ENDURANCE TEST DATA

SYSTEM

FURNACE

RETORT

NOTES

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[redacted]

[redacted]

TABLE III

UNCLASSIFIED

S8DRM-1 Developmental Test

FUEL ELEMENT NUMBER	E-1041[redacted]-4		
N_H	1.6		
w/o A	0.15		
ϕ_{1400} Acceptance	0.16		
ϕ_{1300} Pre Thermal Soak	0.02		

ENDURANCE TEST DATA

SYSTEM

FURNACE

RETORT

NOTES

ENDURANCE TEST DATA

DATE STARTED

PRETEST TOTAL ϕ =

HOURS	ϕ	HOURS	ϕ

DATE FINISHED

UNCLASSIFIED

[redacted]

TABLE IV

UNCLASSIFIED

S8DRM-1 Developmental Test

FUEL ELEMENT NUMBER	E-1044E-4			
N_H	1.6			
w/o A	0.15			
ϕ_{1400} Acceptance	0.14			
ϕ_{1300} Pre Thermal Soak	0.02			

ENDURANCE TEST DATA

DATE STARTED

PRETEST TOTAL ϕ =

HOURS	ϕ	HOURS	ϕ

DATE FINISHED

ENDURANCE TEST DATA

SYSTEM

FURNACE

RETORT

NOTES

UNCLASSIFIED

[redacted]

[redacted]

TABLE V

UNCLASSIFIED

S8DRM-1 Developmental Test

FUEL ELEMENT NUMBER	B-1063N-4		
K_H	1.6		
w/o A	0.14		
ϕ_{1400} Acceptance	0.52		
ϕ_{1300} Pre Thermal Soak	0.12		

ENDURANCE TEST DATA			
DATE STARTED			
PRETEST TOTAL ϕ =			
HOURS	ϕ	HOURS	ϕ
DATE FINISHED			

ENDURANCE TEST DATA

SYSTEM

FURNACE

RETORT

NOTES

UNCLASSIFIED

[redacted]

[redacted]

TABLE VI

UNCLASSIFIED

S8DRM-1 Developmental Test

FUEL ELEMENT NUMBER	E-1064N-4		
N_H	1.6		
w/o A	0.15		
ϕ_{1400} Acceptance	0.30		
ϕ_{1300} Pre Thermal Soak	0.04		

ENDURANCE TEST DATA

SYSTEM

FURNACE

RETORT

NOTES

ENDURANCE TEST DATA

DATE STARTED

PRETEST TOTAL ϕ =

HOURS	ϕ	HOURS	ϕ

DATE FINISHED

UNCLASSIFIED

[redacted]

[redacted]

TABLE VII

UNCLASSIFIED

S8DRM-1 Developmental Test

FUEL ELEMENT NUMBER	E-1066N-4			
N_H	1.6			
w/o A	0.13			
ϕ_{1400} Acceptance	0.16			
ϕ_{1300} Pre Thermal Soak	0.01			

ENDURANCE TEST DATA

SYSTEM

FURNACE

RETORT

NOTES

ENDURANCE TEST DATA

DATE STARTED

PRETEST TOTAL ϕ =

HOURS	ϕ	HOURS	ϕ

DATE FINISHED

UNCLASSIFIED

[redacted]

[redacted]

TABLE VIII

S8DRM-1 Developmental Test

FUEL ELEMENT NUMBER	E-1070N-4		
N_H	1.6		
w/o A	0.14		
ϕ_{1400} Acceptance	0.14		
ϕ_{1300} Pre Thermal Soak	0.02		

ENDURANCE TEST DATA

SYSTEM

FURNACE

RETORT

NOTES

ENDURANCE TEST DATA

DATE STARTED

PRETEST TOTAL ϕ =

HOURS	ϕ	HOURS	ϕ

DATE FINISHED

[redacted]

[redacted]

TABLE IX

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S8DRM-1 Developmental Test

FUEL ELEMENT NUMBER	E-1089N-4		
N_H	1.6		
w/o A	0.13		
Ø1400 Acceptance	0.17		
Ø1300 Pre Thermal Soak	0.02		

ENDURANCE TEST DATA			
DATE STARTED			
PRETEST TOTAL ϕ =			
HOURS	ϕ	HOURS	ϕ
DATE FINISHED			

ENDURANCE TEST DATA
SYSTEM
FURNACE
RETORT

NOTES

UNCLASSIFIED

[redacted]

[redacted]

TABLE X

UNCLASSIFIED

S8DRM-1 Developmental Test

FUEL ELEMENT NUMBER	E-1119[illegible]-4		
N_H	1.6		
w/o A	0.14		
$\not{0}_{1400}$ Acceptance	0.21		
$\not{0}_{1300}$ Pre Thermal Soak	0.03		

ENDURANCE TEST DATA

SYSTEM

FURNACE

RETORT

NOTES

ENDURANCE TEST DATA			
DATE STARTED			
PRETEST TOTAL ϕ =			
HOURS	ϕ	HOURS	ϕ
DATE FINISHED			

UNCLASSIFIED

[redacted]

[redacted]

TABLE XI

UNCLASSIFIED

S8DRM-1 Developmental Test

FUEL ELEMENT NUMBER	E-1129N-4		
N_H	1.6		
w/o A	0.14		
Ø1400 Acceptance	0.24		
Ø1300 Pre Thermal Soak	0.04		

ENDURANCE TEST DATA			
DATE STARTED			
PRETEST TOTAL ϕ =			
HOURS	ϕ	HOURS	ϕ
DATE FINISHED			

ENDURANCE TEST DATA

SYSTEM

FURNACE

RETORT

NOTES

UNCLASSIFIED

[redacted]

[redacted]

TABLE XII

UNCLASSIFIED

S8DRM-1 Developmental Test

FUEL ELEMENT NUMBER	E-1133E-4		
N_H	1.7		
w/o A	0.14		
ϕ_{1400} Acceptance	0.12		
ϕ_{1300} Pre Thermal Soak	0.02		

ENDURANCE TEST DATA

SYSTEM

FURNACE

RETORT

NOTES

ENDURANCE TEST DATA			
DATE STARTED			
PRETEST TOTAL ϕ =			
HOURS	ϕ	HOURS	ϕ
DATE FINISHED			

UNCLASSIFIED

[redacted]