13. A17

AEC
RESEARCH REPORTS

221 NAA-SR-10132

UNIVERSITY OF
ARIZONA LIBRARY

Document Collection

DEC 24 1964

NAA-SR-10152

COPY

DESIGN OF AN EXPERIMENTAL
BOWABLE FUEL ELEMENT
FOR THE SRE

AEC Research and Development Report

ATOMICS INTERNATIONAL

A DIVISION OF NORTH AMERICAN AVIATION, INC.

metadc304055

— LEGAL NOTICE —

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Price \$.50
Available from the Office of Technical Services
Department of Commerce
Washington 25, D. C.

DESIGN OF AN EXPERIMENTAL
BOWABLE FUEL ELEMENT
FOR THE SRE

By
C.L. PECKINPAUGH

ATOMICS INTERNATIONAL

A DIVISION OF NORTH AMERICAN AVIATION, INC.
P.O. BOX 309 CANOGA PARK, CALIFORNIA

CONTRACT: AT(11-1)-GEN-8
ISSUED: OCT 15 1964

DISTRIBUTION

This report has been distributed according to the category "Reactor Technology" as given in "Standard Distribution Lists for Unclassified Scientific and Technical Reports" TID-4500 (32nd Ed.), July 1, 1964. A total of 660 copies was printed.

CONTENTS

	Page
Abstract	4
I. Introduction	5
II. Description	7
A. General	7
B. Fuel Rod Cluster	7
C. Cluster Hanger	11
D. Shield Plug	11
E. Thermocouples	13
III. Results	14
A. Mechanism	14
B. Seals	15
C. Shielding	16
D. Thermocouples	16
IV. Conclusions	17
References	18

TABLES

Radiation Measurements	16
----------------------------------	----

FIGURES

1. Standard Core-II Fuel Element.	6
2. Bowable Element Schematic	8
3. Bowable Element General Configuration	9
4. Bowable Element Fuel Bundle	10
5. Bowable Spring Assembly	10
6. Springs Banded to Fuel Rods	10
7. Fuel Rods in, Locking Springs Bowed Out	12
8. Fuel Rods and Locking Springs Bowed Out	12
9. Bowing Actuator Screw and Seal Assembly	14
10. Exit Thermocouple Installation.	15
11. Element Assembly Drawing	19

ABSTRACT

An experimental bowable fuel element was developed to study temperature oscillations in the second core loading of the SRE. The bowable element featured two sets of wire spring mechanisms which were remotely operated during at-power reactor operation. One set bowed the five fuel rods outward to the coolant channel wall while the second set extended between the fuel rods to the channel wall. Miniature thermocouples were mounted on the springs and throughout the cluster.

The spring mechanisms operated successfully during full power reactor operation in a high-temperature sodium environment. Epoxy seals for thermocouple penetrations through shield plugs were adequate; however, difficulty was experienced with core gas leakage past dynamic O-ring seals for spring actuators. Radiation streaming from straight-through gaps in shield plug penetrations for actuators and thermocouples was below permissible exposure rates. The miniature thermocouples had a 92% reliability over the one month of experimental operation.

ACKNOWLEDGMENT

The author wishes to acknowledge the excellent design and assembly efforts of Mr. M. E. Rogers and Mr. C. H. Whitney in development of the experimental bowable fuel element.

I. INTRODUCTION

Large fuel-element temperature oscillations were observed as the power level of the SRE, with the second core loading of thorium-uranium fuel, was increased to 50% of full power. Initial tests indicated that bowing the fuel rods out toward the process channel wall sharply reduced temperature oscillations but did not isolate the specific cause for oscillations. An experimental bowable fuel cluster which could be operated remotely during power operation was designed, assembled, and used in experiments to determine the cause. Results of these experiments including overall work on temperature oscillations are reported in References 1, 2, and 3. This report discusses the detail design of the bowable element and the mechanical operating results during at-power reactor operation.

9-10-64

7602-5179

Figure 1. Standard Core-II Fuel Element

II. DESCRIPTION

A. GENERAL

The bowable element was designed to closely simulate the standard SRE Core II fuel cluster (Figure 1). Standard 5.4% Th - U wire-wrapped fuel rods were assembled about a central support tube to form a 5-rod cluster with identical rod spacing and cluster dimensions as the Core II element. The bowing mechanisms featured two sets of wire springs which were built into the cluster central tube. Outward radial motion was obtained by fixing the bottom end of the springs and pushing at the top similar to the action of an automotive scissors jack. The first set of springs was attached to the fuel rods and designed to bow the five rods outward to the process channel wall. The second set of springs was located between the rods and designed to move outward between the rods to the process channel wall, thus centering and locking the cluster in position within the channel. A schematic of this bowing action is shown in Figure 2. The springs were operated independently and remotely at the top of the shield plug. Figures 3 and 11 show the entire mechanism which was designed to bow the rods or hold the cluster in a controlled and positive manner and to provide accurate knowledge of rods or cluster position when at full power.

B. FUEL ROD CLUSTER

The fuel rod cluster (Figure 4) consisted of 5 Core II fuel rods equally spaced around a central support assembly. The rods were supported and fixed at the top and guided at the bottom to permit thermal expansion of individual rods. This top and bottom cluster hardware was identical to that used in Core II elements. The upper half of the central support was a 0.375-in. OD by 0.049-in. wall tube which contained both push-pull spring actuators. The cluster locking actuator was a 0.250-in. OD by 0.035-in. wall tube which moved axially inside the central support tube. The fuel bowing actuator was a 0.157-in. -diameter rod which was positioned and moved axially inside the cluster-locking actuator tube; thus a 0.015-in. radial clearance was provided between each actuator for smooth operation.

The fuel-bowing actuator rod extended slightly past the cluster-locking actuator tube to provide clearance for attachment of springs. The two sets of

9-10-64

7602-5180

Figure 2. Bowable Element Schematic

9-10-64

7602-5181

Figure 3. Bowable Element General Configuration

NAA-SR-10152

9-10-64 7602-5182

Figure 4. Bowable
Element Fuel
Bundle

9-10-64

7602-5183

9-10-64 7602-5184

Figure 6. Springs Banded
to Fuel Rods

Figure 5. Bowable Spring
Assembly

springs were welded to the ends of their respective actuators and passed through slots to the outside of the surrounding central support tube. The bottom end of the springs were welded to the outside of element central support. This spring assembly is shown in Figure 5. The lower half of the element central support, below the springs, consisted of a 0.375-in.-diameter solid rod. All actuator material was Type 304 stainless steel. The springs were made from 0.090-in.-diameter Type 304 stainless steel spring wire which is the identical material used for Core II fuel rod wire wraps.

The bowing springs were located at the center of the rod length which was 10 in. above the core centerline. Each fuel rod was attached to its associated spring by spot welding a band of 0.004-in. stainless steel shim stock around the spring and fuel rod as shown in Figure 6.

C. CLUSTER HANGER

The fuel rod cluster is suspended from the shield plug with a cluster hanger tube. This tube extends from the top of the fuel bundle up through the shield plug to the reactor loading face. Above the fuel bundle the spring actuator rod was increased to 0.375-in.-diameter and the tube to 0.687-in. OD by 0.120-in. wall. Both rod and tube extended up to the reactor loading face inside the 1-in. OD by 0.120-in. wall cluster hanger tube; thus both rod and tube actuators had 0.030-in. radial clearance above the rod bundle for smooth operation within the hanger tube.

D. SHIELD PLUG

The shield plug consisted of a hollow SRE shield plug shell with straight through penetrations for bowing spring actuators and thermocouples. Two feet of lead shot was provided above the plug step with the lower section remaining empty.

The actuator penetration was located in the center of the plug and was formed by the extension of the cluster hanger tube with the two actuators positioned inside. The cluster hanger tube was welded to the bottom of the shield plug to provide a gas tight seal. Two sets of double O-ring seals were provided between the actuator rod and tube and between the actuator tube and hanger tube to provide core gas containment. The seals were designed so that the O-rings may be replaced.

9-10-64 7602-5185

Figure 7. Fuel Rods
in, Locking Springs
Bowed Out

9-10-64 7602-5186

Figure 8. Fuel Rods
and Locking Springs
Bowed Out

The up and down axial movement of spring actuators was obtained with simple screw mechanisms. Counter-clockwise rotation of the single center screw pushed the rod actuator down thus bowing the smaller springs and attached fuel rods outward. Figures 7 and 8 show the fuel rods in the normal and bowed positions. Likewise, small incremental counter-clockwise rotation of the two offset screws pushed the tube actuator down and bowed the cluster locking springs outward. Four additional screws were used to provide an adjustable mechanical stop to prevent over bowing and provide a positive reference position. The screw mechanism was designed so that the fuel-bowing and cluster-locking springs could be moved over the full range of travel completely independent of each other. This bowing-actuator screw and seal assembly is shown in Figure 9.

The thermocouple penetration consisted of a straight 0.375-in. OD by 0.049-in. wall tube which was welded to the bottom of the shield plug to provide a gas seal. The tube extended up through the shield plug to the reactor loading face forming a straight through conduit for 25 thermocouples, 0.025-in.-diameter. A gas seal was made between the thermocouples and the tube in the cold top region of the tube, with epoxy.

E. THERMOCOUPLES

Twenty-five miniature (0.025-in.-diameter) thermocouples were located within the fuel cluster to measure temperature oscillation characteristics at various fuel rod and cluster positions. All thermocouples were chromel-alumel with magnesium oxide insulation and Type 304 stainless steel sheaths. The thermocouples extended from the hot junction in the cluster through the shield plug and seal to the reactor loading face where a transition was made from the stainless steel sheath to flexible wire. To maintain maximum reliability, no brazing or welding was permitted on the thermocouple sheath. An epoxy seal was used at the top of shield plug and all thermocouples were held in position with spot welded 0.002-in. stainless steel bands.

The installation of the five exit thermocouples is shown in Figure 10. Seven thermocouples were mounted on the central cluster support with a typical example shown in Figure 4. The remaining thermocouples were installed on the outside of the fuel rods at the rod wire wrap and on each moving cluster locking spring. Figures 5, 7, and 8 show the installation of these thermocouples.

9-10-64

7602-5187

Figure 9. Bowing Actuator Screw and Seal Assembly

III. RESULTS

A. MECHANISMS

An operational checkout and calibration of actuator screw turns versus fuel rod and locking spring positions was performed before insertion of the element into the reactor. Throughout the checkout, both rod-bowing and cluster-locking mechanisms operated smoothly with a maximum torque of 20 in. -lb. The calibration indicated that rod and locking spring positions could be reproduced consistently within 0.015 of an inch over the complete travel range of 0.160 in. The locking springs secured the element tightly in the channel. However, due to fabrication tolerances associated with a first-time assembly, the element was not concentric when locked into position, but was offset 0.060 in.

The element was operated in the reactor for the last month of Core II operation which included full power conditions at 20 Mwt and 900°F outlet. The bowing mechanisms continued to operate smoothly and successfully throughout this period and were working properly at the final Core II shutdown. It is

9-10-64 7602-5188

Figure 10. Exit
Thermocouple Installation

conservatively estimated that the springs were cycled at least 100 times during at-power experiments with no change in actuator torque. Temperature data indicated that accurate knowledge and good reproducibility of spring and fuel rod positions was also maintained during all experiments.

B. SEALS

The epoxy seal around the 25 thermocouples was helium-leak checked in the laboratory before installation into the shield plug. No leaks were detected, indicating that a successful seal had been made by use of this technique.

The double O-ring seals around the sliding actuators were pressure checked before insertion in the reactor and found to be satisfactory. However, shielding studies during power operation indicated that core gas was leaking from the shield plug. The most likely source of leakage was the sliding O-ring seals. The radiation level of the leaking gas indicated that the leak was larger than could be tolerated in a nonexperimental, standard shield plug.

C. SHIELDING

Radiation measurements were made over the experimental bowable element to determine the magnitude of streaming from the two straight through 0.030-in. radial gaps around the bowing actuators and from the straight thermocouple conduit tube. These measurements were made at full power (20 Mwt) with sodium activation at equilibrium. Radiation levels were obtained by x-ray and film badge exposure.

All measurements were duplicated with consistent results obtained in all cases. The results are shown in the table below.

RADIATION MEASUREMENTS

Location	Radiation Streaming	
	Gamma	Neutron
1. Loading face control	<u>2 mrem</u> hr	No neutrons found
2. Bowable element (R-58)		
a) Background	<u>3 mrem</u> hr	No neutrons found
b) TC conduit	Background	and no streaming
c) Push-rod, tube gaps maximum reading	<u>6 mrem</u> hr	No neutrons found

These measurements show that the general radiation background and streaming from the bowable element shield plug was below permissible exposure rates and, thus the shielding configuration was adequate.

D. THERMOCOUPLES

Resistance measurements were made to check out the thermocouples before insertion in the reactor. These measurements indicated that 2 out of the 25 thermocouples were faulty due to damage during installation. Isothermal and at-power temperature data confirmed that these two thermocouples were inoperative. Temperature data and resistance measurements at the end of the one-month operational period indicated that the remaining 23 thermocouples were still functioning properly. In addition, observation of the element in the SRE fuel handling machine, after removal from the reactor, showed that fastening bands were in good condition.

IV. CONCLUSIONS

1. Successful operation of the spring bowing mechanisms is further proof that simple mechanisms with 0.015- to 0.030-in. clearances may be operated reliably in a high-temperature sodium environment.

2. Thermocouple penetrations in sodium reactor shield plugs may be adequately sealed with epoxy in the cold top region of the plug. This sealing technique replaces methods which required welding or brazing on the thermocouple sheath and, thus will increase thermocouple reliability.

3. Core gas leakage past the sliding actuator O-ring seals demonstrated that, where possible, O-rings should be avoided as dynamic seals for mechanisms such as variable orifices which penetrate sodium reactor shield plugs.

4. The low radiation levels measured over the bowable element provide experimental proof that radiation streaming through small gaps and tubes is less severe than past calculated estimates indicate. This result will permit shield plug penetrations such as thermocouples and variable orifice drives to avoid complicated steps and offsets.

5. The 92% reliability of the 0.025-in.-diameter thermocouples demonstrates that miniature thermocouples may be used with a satisfactory degree of reliability for short experimental measurements in high-temperature sodium systems.

REFERENCES

1. C. L. Peckinpaugh et al., "Temperature Oscillations In The SRE," NAA-SR-10151
2. C. L. Peckinpaugh, "Temperature Distributions in the SRE Core II Fuel Element," NAA-SR-10153 (To be published)
3. C. L. Peckinpaugh, "Analysis of Temperature Oscillations in the SRE," NAA-SR-10154 (To be published)
4. C. Starr and R. W. Dickinson, Sodium Graphite Reactors, Addison-Wesley, Reading, Massachusetts (1959)

9-10-64

7602-5189

Figure 11. Element As-
sembly Drawing
NAA-SR-10152
19