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November 10, 1961

HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

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TITLE

PT-IP-344-A-FP, EVALUATION OF AL-SI BOND
CHARACTERISTICS

7

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Page 1

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JW Runkle

November 10, 1961

PT-IP-344-A-FP, EVALUATION OF AL-SI BOND CHARACTERISTICS

INTRODUCTION

Tests in which aluminum-jacketed, Al-Si bonded uranium fuel elements were baked at various temperatures have shown there is a time-temperature relationship for Al-Si layer decomposition. For heat transfer and secondary coolant barrier considerations, the extent of bonding layer deterioration* during fuel element

*In the sense that bond separation, extensive aluminum or uranium diffusion, or deformation of void areas which may decrease heat conductance are forms of deterioration.

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HW-65870 C

Page 2

irradiation is important. Currently, Al-Si bonded fuel elements show evidence of spire bond separation, and to a lesser degree, can-bond separation following irradiation.^(1,2) Such evidence has aroused concern for the ability of the currently produced Al-Si bonded fuel elements to withstand future reactor operating conditions.

Several potential uranium fabrication and canning process improvements are being developed to further advance fuel element stability and performance. Optimization of process conditions based on these improvements may provide the necessary margin of safety for good bond layer integrity, but before a decision can be made to continue improvement of the present process or convert to a new canning process, more information on the stability of the present fuel element bond is needed. This report presents the irradiation phase of a test which was designed to more fully evaluate Al-Si bond integrity under anticipated future reactor conditions.

OBJECTIVE

The objective of this test is to evaluate the relative stability of Al-Si as a fuel element core-to-jacket bonding medium at various specific powers and exposures (up to 120 KW/ft and 1600 MWD/T).

TEST SUMMARY

Seventeen (17) columns of I&E fuel elements representing three enrichment levels will be irradiated to incremental goal exposures up to 1600 MWD/T in the C Reactor smooth-bore zirconium tube facility.* Bond layers of selected elements from each enrichment level will be examined in the Radiometallurgy Laboratory to determine relative Al-Si bond stability.

DISCUSSION

For several years a program has been undertaken to improve the quality** of the Al-Si bond obtained from the lead-dip canning process. During this period, improvements in bond quality have been achieved by incorporation of canning process improvements; however, periodic concern about the stability of the Al-Si bond at proposed reactor power and exposure goals has lead to the investigation of alternate cladding techniques including: hot-press canning,⁽³⁾ extrusion cladding,^(4,5) and vacuum canning⁽⁶⁾ processes. In each instance, however,

* Non-overbore Size Tube - 69 Tubes In-reactor.

** Best Combination of Strength, Toughness, and Soundness.

- (1) HW-59756 C, "Production Test IP-247-A-8-FP, Irradiation of 1.47% Enriched Self-Supported I&E Fuel Elements in Ribless Process Tubes". RE Hall, 7/29/59 (SECRET)
- (2) HW-66106, "Radiometallurgy Examination of 1.47% Enriched I&E Fuel Elements Under PT-IP-247-A". R. Teats, July 19, 1960 (CONFIDENTIAL).
- (3) HW-61995, "Specifications, Laboratory Hot Press Process for "C" Size I&E Fuel Elements". JC Tverberg, 9/25/59 (SECRET).
- (4) HW-56801, "Extrusion Cladding Uranium with Aluminum Using the "Schloemann" Cable-Cladding Press-Mechanical Aspects. GF Jacky, 7/21/58 (UNCLASSIFIED).
- (5) HW-56802, "Evaluation of Extrusion Clad Hanford Fuel Elements-Metallography, Corrosion and Jacket-Core Bonding". GF Jackey, 8/25/58 (CONFIDENTIAL).
- (6) HW-57692, "Evaluation of Vacuum-Canned and Hot Press Fuel Elements, PT-IP-44-A and IP-45-A". EA Smith, 10/15/58 (SECRET).

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HW-65870 C

Page 3

Al-Si process improvements were either adequate to make it competitive economically or certain alternate cladding process deficiencies were encountered which were of a magnitude sufficient to preclude their adaptation.

In view of the proposed IPD program for increased reactor power and coolant temperatures over the next several years, ⁽⁷⁾ and with no alternate fuel element cladding techniques under evaluation, the necessity for initiating new studies in late FY 1962 depends on the stability of the Al-Si bond under the projected conditions.

To date, a single production test has been specifically conducted to measure the stability of the Al-Si bond under irradiation. ⁽⁸⁾ All other bond quality tests have been conducted out of reactor. There has been no correlation between out-of-reactor and in-reactor tests.

Since there is no out-of-reactor test which will demonstrate the ability of the Al-Si bonding layer to withstand future irradiation conditions, a small-scale irradiation test under closely controlled conditions appears to offer the best answer to the question of Al-Si bond stability. ⁽⁹⁾ This test involves closely monitored irradiation of high quality Al-Si bonded fuel elements of varied enrichment levels. Three enrichment levels will be used to bracket the fuel element specific powers expected from present and future irradiation conditions. Columns from each enrichment level will be discharged at predetermined exposures to permit characterization of the bonding layer at various power and exposure levels. The high quality fuel elements will be fabricated by the standard process, incorporating the following process improvements:

- a. Utilization of can and sleeve vibration and spire pulsing in the canning baths to reduce braze porosity and to facilitate cap-spire wetting.
- b. Utilization of longer component preheat times and lead plugged cores to obtain maximum braze integrity and strength.
- c. Utilization of pressurized quench to reduce braze porosity (primarily at the cap end). Additional ex-reactor testing to characterize bond quality will include high pressure autoclave, sectioning and metallography of autoclaved and unautoclaved pieces, stud pulling of autoclaved and unautoclaved pieces, and modification of ultrasonic bond testing equipment to better characterize the bond condition, both before and after irradiation of the load.

The fuel elements should have bonding layers representative of the quality expected to be produced in CY 1962-65.

(7) HW-67952, "Plant Improvement Program, Irradiation Processing Department, FY 62-71", AB Greninger, 1/12/61 (SECRET)

(8) HW-58929, "Production Test IP-229-A, Evaluation of the Uranium - Al-Si Bond at High Temperature", WK Kratzer, 1/10/59 (SECRET).

(9) HW-65851, "Potential Limitations of Al-Si Bonded Fuel Elements", WH Hodgson, 7/14/60.

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HW-65870 C
Page 4

TEST DETAILS

1. Reactor

The test will be conducted at C Reactor.

2. Material

A. Fuel Elements

- 1) Details of the test material fabrication, ex-reactor testing and pre-irradiation measurements may be found in HW-65870-A⁽¹⁰⁾. The following table has been extracted for reference purposes:

<u>Nominal Dimension (Inches)</u>	<u>Enrichment Level - Fuel Model</u>		
	<u>Natural</u>	<u>0.947% E</u>	<u>1.47% E</u>
	<u>CVNS</u>	<u>CIVES</u>	
Core OD	1.406	1.406	1.406
Core ID	0.488	0.488	0.488
Core Length	8.325	6.000	7.000
Finished fuel OD	1.494	1.494	1.494
Finished fuel ID	0.375	0.375	0.375
Finished fuel effective length	8.865	6.540	7.540
Support rail height	0.082	0.082	0.082
Maximum Circumscribed circle	1.660	1.660	1.660
Support distance from end of element	1.250	0.500	0.750

Notes

- 1) CVN aluminum cans cut to 8-7/8" length will be used to can the 1.47% E cores.
- 2) Fuel elements are tru-line elements canned in flat base cans.
- 3) Self-support rail material is X-8001 aluminum alloy, 0.032" thick and 2-5/16" long over-all.

All cores for this test will meet quality requirements as outlined in current fuels preparation specifications. The iron and silicon concentration will be adjusted within specified limits⁽¹¹⁾ to yield the same relative uranium grain size in all cores used in this test. Collapsible bridge rail projection supports will be attached using ultrasonic welding techniques.

(10) HW-65870-A REV "Design of Production Test IP-344-A-FP, Evaluation of Al-Si Bond Characteristics", WH Hodgson and MA Clinton, July 10, 1961.

(11) HW-47029, "Process Specifications, Fuel Element Fabrication Processes", FPD (CONFIDENTIAL).

2) Water-mixer elements are not required for this test.

3) Column makeup will be as follows:

<u>Enrichment</u>	<u>Pieces/Column</u>	<u>Columns</u>
Natural uranium	32	8
0.947% E	35	5
1.47% E	18	4

4) Pre-Irradiation Measurements - In brief, the following tests and measurements will be made:

UT-2; SORT; Dimensional measurements of length, OD, ID, and warp on both bare cores and canned fuel elements; Weight of downstream fifteen pieces; Surface Tester; Total bond count; NPR Bond Test; Stud pulling; Autoclave baking; and Metallography.

B. Process Tube

This test material will be charged into the non-overbore size smooth-bore Zircaloy-2 process tubes installed in a Reactor under authorization of PT-IP-272-A-FP(12).

C. Dummies and Seating

Self-supported aluminum spacers described by drawing H-1-12347 will be used in making up the downstream dummy patterns. Self-supported solid aluminum spacers may be required to provide desired flow rates. If required, they will be supplied by the test author along with the recommended makeup pattern to insure that the solid spacers are separated from the I&E fuel elements by a minimum of two perforated spacers. The following downstream dummy lengths will be required:

<u>Enrichment</u>	<u>DSD Length</u>	<u>Pieces</u>
Natural uranium	109"	13-8" & 1-5" pieces
0.947% E	136"	17-8" pieces
1.47% E	184"	23-8" pieces

D. Thermocouple Probes will not be required for this test.

E. Special Venturis

It may be necessary to install modified venturis on the four 1.47% enriched fuel columns in order to obtain sufficient panellet pressure to preclude operation near existing TAI limits. Modified and calibrated venturis will be provided by the test author if needed.

(12) HW-61669 C, "Pilot Test of Self-Supported Fuel Elements In Ribless Zirconium Process Tubes", RE Hall and DH Curtiss, 8/27/59 (SECRET).

3. Irradiation

A. Charging

All fuel columns will be serially numbered and will be charged in numerical order with piece number one downstream. Each column shall have the fuel identification number (series number) recorded opposite the tube number on the front face sequence sheets. The prototype charging machine developed for charging self-supported fuel elements may be used.

While it is desirable to charge all 17 columns in one localized group during the same outage, it is not absolutely necessary. The test is actually composed of three component parts and each part may be considered, if necessary, a separate test group. The charges in each enrichment level are to be considered as a test group and must be charged during the same outage. The channel locations should provide similar irradiation conditions for all tubes in the group and will be selected by the assigned Process Engineer and Physicist with the concurrence of the test author. The tubes will be selected from those available as a result of scheduled discharge. Charging will be followed by a representative of Research and Engineering.

B. Irradiation

During irradiation, daily temperature and flow data shall be recorded for each column on data sheets which will be provided by the test author. These data will be used to calculate corrosion rates, power, and surface temperatures. Based on these data, the loading patterns and discharge schedules may be modified as specified by the test author with the concurrence of the Manager, C Processing.

C. Discharge

All columns from this test will require special pickup and shipment to the 105-C MEF for post-irradiation examination and measurement. The following schedule of discharging is expected to yield maximum information for this test:

<u>Enrichment Level</u>	<u>Tubes Charged</u>	<u>Goal Exposure - MWD/T</u>				
		<u>400</u>	<u>800</u>	<u>1200</u>	<u>1400</u>	<u>1600</u>
Natural uranium	8	1	1	1	2	3
0.947% E	5	1	1	1	1	1
1.47% E	4	1	1	1		1

The discharge schedule for each tube will be provided by the test author after review of initial data.

It is not intended to use ruptures as a basis for determining the stability of the Al-Si bonding layer and the test may be discharged after two failures have occurred provided all columns can be specially picked up.

During discharge operations particular care should be taken to report pertinent observations relative to removal forces and post-discharge handling. Should a failure occur in any of the test columns, it will be extremely desirable to obtain all pieces for examination. If a charge should stick, regardless of the cause, stuck charge and rupture

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HW-65870 C

Page 7

removal procedures will be reviewed by representatives of R&E before use. If a tube cannot be recharged, procedures for operation with an empty tube will be reviewed by representatives of R&E before startup.

D. Operating Conditions and Limits

Following are the expected operating conditions:

<u>Enrichment Level</u>	<u>Tube Flow</u>	<u>Outlet Temp. (Max.)</u>	<u>Tube Power (Max.)</u>
Natural	50	105 to 110°C	1200 to 1400
.947% E	55	105 to 110°C	1300 to 1500
1.47% E	a) 55	105 to 110°C	1200 to 1350
	b) 60	90 to 95°C	1200 to 1350

Operating limits as determined from existing Process Standards for CIVN-S fuel elements will apply to the loading patterns specified on this test*. Water shut-off limits, approved by Process Technology, will be provided prior to charging any of this material.

E. Material Handling

Procedures specified in existing Process Standards for handling and storage of unirradiated and irradiated material will be followed. Attention is called to the 1.47% enriched material which requires more restrictive procedures than those used in handling natural and .947% E uranium fuel.

4. General

A. Duration

Irradiation will require about seven months following charging. This test authorization will terminate on 12-1-62.

B. Schedule

The fuel elements have been fabricated, received pre-irradiation measurements, and delivered to C Reactor storage. It is planned to charge the natural and .947% enriched material on the first outage following approval of this test. Charging of the 1.47% material will be accomplished during a later outage.

C. Post-irradiation Examination

All fuel elements will be kept separated by the tube or series throughout and following examination. All fuel elements will be: (1) visually examined and weaseled, (2) have warp, diameter, and length growth recorded, and (3) be bond tested**. Elements showing more than 20 mils warp,

a) 55 gpm with existing venturi and SA pieces in downstream dummy.

b) 60 gpm with special reamed venturi.

* Personal communication with P. A. Carlson

** Utilizing the same NPR tester employed for obtaining pre-irradiation bond data.

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HW-65870 C
Page 8

length increase, diameter increase, ellipticity, or surface bumping shall be set aside for (a) stripping and bare core measurements of length, diameter, and warp, or (b) shipment to Radiometallurgy Laboratory for further examination. Selected fuel elements will be sent to Radiometallurgy Laboratory for examination of the bonding layer.

D. Costs

All incremental costs associated with the performance of this test may be charged to XXXX-5R24-XXX.73. Outage time requirements are listed below for scheduling purposes:

<u>Job</u>	<u>Processing Time</u>	<u>Elevator Time</u>
Charge tube	1/4 mh/tube	1/6 hr/tube
Special pickup	1/2 mh/tube	-----
Venturi charge	1/4 mh/tube	1/4 hr/tube

E. Hazards

Hazards peculiar to this test are primarily associated with the presence of the self-support projections on the fuel surface. It is conceivable that these self-supported elements could stick tighter than do non-supported elements since the supports restrict fuel displacement within the process tube; however, it appears that no extreme risk is involved in this testing program with regards to safety.

RESPONSIBILITIES

Fuels Preparation Department

Manufacturing Section shall be responsible for fabrication of all elements used in this test, providing the elements to others for attachment of the projections, element quality, and pre-exposure measurements of all pieces.

Engineering Section shall be responsible for attachment of the projections, liaison contact and coordination of the 300 Area portion of the test.

Irradiation Processing Department

Research and Engineering Section

Process Technology Sub-Section will be responsible for providing assistance in pre-shutdown scheduling and charging, reporting of operating data to the author, for specifying of operating limits and for specifying column locations.

Process and Reactor Development Sub-Section shall be responsible for coordination of the test, analysis of operating data, reporting of in-reactor performance, and for provision of bases for operating limits.

Operational Physics Sub-Section shall be responsible for assistance in choice of test location and reactivity changes required.

DECLASSIFIED

HW-65870 C

Page 9

Component Testing Unit shall be responsible for post-irradiation fuel element examination and measurements.

B-C Reactor Operation

C Processing Operation shall be responsible for scheduling, the operational safety, and production continuity of the reactor, charging of test material under the direction of a representative of Research and Engineering for collection of operating data, and for special pickup.

C Maintenance Operation shall be responsible for all maintenance required by this test.

M. A. Clinton

Reactor Fuels Unit
Process and Reactor Development
Research and Engineering
IRRADIATION PROCESSING DEPARTMENT

MA Clinton/gb

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HW-65870 C
Page 10

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