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DESIGN OF PRODUCTION TEST IP-344-A-FP,

DETERMINATION OF THE LIMITATIONS OF THE Al-Si PROCESS

W. H. Hodgson and M. A. Clinton

August 31, 1960

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DESIGN OF PRODUCTION TEST IP-344-A-FP, DETERMINATION OF THE LIMITATIONS OF THE Al-Si PROCESS

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 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. 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 design of a test to more fully evaluate Al-Si bond integrity under anticipated future reactor operating conditions.

OBJECTIVES

The objectives of this test are to determine the limitations, if any, of Al-Si as a fuel element core-to-jacket bonding medium, and to compare stability of standard quality and optimum quality Al-Si bond layers at various specific powers (up to 120 KW/ft.), and exposures (up to 1600 MWD/T).

SUMMARY OF TEST

Thirty-four (34) columns of I & E fuel elements representing three enrichment levels, each containing standard quality and optimum quality Al-Si core-to-jacket bonds will be irradiated to incremental exposure goals to 1600 MWD/T in C Reactor ribless tube facility. Bond layers of selected elements of each category will be examined in the Radiometallurgy Laboratory to determine relative Al-Si bond stability.

---

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

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". R. E. Hall. 7/29/59. (Secret)
2. HW-66106, "Radiometallurgy Examination of 1.47 Percent Enriched I & E Fuel Elements Under PT-IP-247-A". R. Teats. July 19, 1960. (Conf.)

[redacted]

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. From time to time, however, concern about the stability of the Al-Si bond at proposed reactor power and exposure goals has lead to evaluation of alternate cladding techniques including: hot-press canning,[3] extrusion cladding,[4,5] and vacuum canning[6] processes. In each instance, however, 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 further evaluation.

In view of the proposed IPD program for increased reactor power and coolant temperatures over the next five years,[7] and with no alternate fuel element cladding techniques under study, the necessity for initiating new studies in 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 limitations. This test involves closely monitored irradiation of standard and optimum quality bonded fuel elements of varied enrichment levels. The three enrichment levels will bracket fuel element specific power experienced under present and future irradiation conditions. A pair of columns of each enrichment level, composed of alternated standard and optimum quality bonded fuel elements, will be discharged at predetermined exposures to permit characterization of the bonding layer at various power and exposure levels. The optimum quality fuel elements will be fabricated by the standard process, incorporating process improvements to achieve the following:

---

* Best combination of strength, toughness, and soundness.

3. HW-61995, "Specifications, Laboratory Hot Press Process for "C" Size I & E Fuel Elements". J. C. Tverberg. 9/25/59. (Secret)
4. HW-56801, "Extrusion Cladding Uranium with Aluminum Using the 'Schloemann' Cable-Cladding Press-Mechanical Aspects". G. F. Jacky. 7/21/58. (Uncl.)
5. HW-56802, "Evaluation of Extrusion Clad Hanford Fuel Elements-Metallography, Corrosion and Jacket-Core Bonding". G. F. Jacky. 8/25/58. (Confidential)
6. HW-57692, "Evaluation of Vacuum-Canned and Hot Press Fuel Elements - PT-IP-44-A and IP-45-A". E. A. Smith. 10/15/58. (Secret)
7. HW-62862, "Plant Improvement Program, Irradiation Processing Department". A. B. Grenninger. 4/1/60. (Secret)
8. HW-58929, "Production Test IP-229-A, Evaluation of the Uranium - Al-Si Bond at High Temperature". W. K. Kratzer. 1/10/59. (Secret)

a. Improved component cleaning and vibration of the components in the canning baths to facilitate wetting and reduce braze porosity.

b. Utilization of optimized canning assembly process for maximum braze integrity and strength.

c. Isolation of the effects of sources of hydrogen pickup in canning baths for tighter braze porosity control.

d. Utilization of pressurized quenching of assembled fuel elements to minimize braze porosity (primarily at cap).

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

Additional ex-reactor testing to characterize bond quality of standard and optimum quality fuel elements will include high pressure autoclave, sectioning and metallography of autoclaved and un-autoclaved pieces, stud pulling of autoclaved and un-autoclaved pieces, and modification of ultrasonic bond testing equipment to better characterize the bond condition, both before and after irradiation of the load.

FABRICATION OF TEST MATERIAL

Components

Components and finished fuel element dimensions are listed in the table below:

		Enrichment			
		Natural CVNS	0.97% CIVES	1.47%	Notes
a.	Can OD (Nominal)	1.490"	1.490"	1.490"	Use CVNS cans cut to 8-7/8" length.
b.	Spire ID (Nominal)	0.375"	0.375"	0.375"	
c.	Core OD (Nominal)	1.406"	1.406"	1.406"	
	ID (Nominal)	0.488"	0.488"	0.488"	
	Length (Nominal)	8.325"	6.000"	7.000"	
d.	Finished Element OD (Nominal)	1.494"	1.494"	1.494"	
	ID (Nominal)	0.375"	0.375"	0.375"	
	Length (Nominal)	8.965"	6.640"	7.640"	
	Component Code	W	U	W	
	Nominal Support Height	0.080"	0.080"	0.080"	
	Maximum Circumscribed Circle	1.660"	1.660"	1.660"	

All cores for this test will meet quality requirements as outlined in current fuels preparation specifications. The iron and silicon concentration will be adjusted, with specified limits[9] to yield the same relative grain size in cores in all enrichment levels. Supports may be either bridge rail and/or end spider collapsible design.

Assembly

All fuel elements shall be fabricated by the "F" Process.[9] The standard process will be used to prepare the control elements. Process improvements described in the "Discussion" will be incorporated to produce the optimum quality fuel elements for this test.

Quality of Material

Quality control measures will be applied in fabrication of all fuel elements.

Quantity of Material

Acceptable fuel elements of the six categories shown below will be required:

	Standard Quality	Optimum Quality
Normal Enrichment	272	272
0.94% Enrichment	200	200
1.47% Enrichment	85	85

TESTING

Pre-irradiation Testing and Measurements

1. The following tests and measurements will be made:

Test	Purpose	Core Status	
UT-2	Grain Size Measure	Bare	Memoscope Pictures
SORT	Orientation Measure	Bare	Record Data
Length	Core Dimensions	Bare and Canned	Record Data
Outer Diameter (3)	Core Dimensions	Bare and Canned	Record Data
Inner Diameter (3)	Core Dimensions	Bare and Canned	Record Data

9. HW-47029, "Process Specifications, Fuel Element Fabrication Processes" - Fuels Preparation Department. (Confidential)

(Continued)

Test	Purpose	Core Status	
Warp	Core Dimensions	Bare and Canned	Record Data
Weight	Core Dimensions	Canned	Record Data
Surface Tester	Core Surface Quality	Bare	Record Data
Total Bond Count	Braze Porosity	Canned	Memoscope Pictures
Stud Pulling	Bond Strength	Canned (MS Rejects)	Record Data
Metallography 10-20 Pcs. as Stds.	Bond Quality	Canned (MS Rejects)	Photomicrographs
Autoclave Baking With	Bond Quality	Canned (MS Rejects)	Record Data
Stud Pulling and Metallography	Bond Quality	Canned (MS Rejects)	Photomicrographs

2. The letter "A" in the lot number will serve as an index mark for the memoscope pictures.

3. Identity and position of measured fuel elements will be recorded by a series and position number stamped on the base of each element.

4. Charges will be made up of alternated standard and optimum quality in each enrichment level. Column length will be established later. Tentatively, column lengths are expected to be as follows:

	Natural Enriched	0.94% Enriched	1.47% Enriched
Standard Quality	32 Pieces	35 Pieces	20 Pieces
Optimum Quality	32 Pieces	35 Pieces	20 Pieces

Standard Quality material will serve as controls in each enrichment level.

Irradiation Test

Sixteen (16) columns of natural enriched (CVNS), ten columns of 0.94 percent enriched (CIVES), and eight columns of 1.47 percent enriched I & E fuel elements will be charged into the zirconium ribless tube facility in C Reactor.

The following schedule of discharging is expected to yield maximum information for this test:

[redacted]

[redacted]

Enrichment Level	Tubes Chgd.	Goal MWD/T						
		400	600	800	1000	1200	1400	1600
Natural	16	2	2	2	2	2	2	4
0.94% E	10	2		2		2	2	2
1.47% E	8	2		2		2		2

It is not intended to use ruptures as a basis for determining the limitations of the Al-Si bonding process.

Post-irradiation Examination

All fuel elements will be kept separated by 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, length increase, diameter increase, eliptticity, or surface bumping shall be set aside along with adjacent control piece 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.

TEST AUDIT

Notebook HW-65870 is to be used to record all data pertaining to this test. Any unusual incidents, whether or not they seem important at the time, are to be recorded in the notebook. The appendix to this report contains a list of items to be used as a guide for preparation of the notebook.

TEST LIMITATIONS AND HAZARDS

Precautions for handling and storage of the unirradiated enriched uranium for this test are outlined in specification NS4.0 in HW-47013.[10]

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Process Engineering
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M. A. Clinton
M. A. Clinton, Engineer
Research and Engineering
Irradiation Processing Department

MAC/WHH/gw

10. HW-47013, "Nuclear Safety Specifications, Fuel Element Manufacturing Process". Fuels Preparation Department. (Confidential)

[redacted]

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APPENDIX

Data to be Recorded in Production Test Notebook

I. Fuel Element Core

   A. Lot Numbers

      1. Ingot Numbers and Chemical Analysis
      2. Unusual Treatment

   B. Finished Dimensions (Pre-Assembly)

II. Aluminum Components

   A. Lot Numbers

      1. Alloy Type
      2. Unusual Treatment

   B. Finished Dimensions (Pre-Assembly)

   C. Pre-Assembly Treatment (Cutoff, Sizing, Inspection)

III. Pre-Assembly Treatment of Cores

   A. UT-2-Record Data - Memoscope Pictures

   B. SORT-Record Data

   C. Surface Tester-Record Data

   D. Measure Length, OD, ID, and Warp of All Cores

IV. Assembly Process

   A. Process Used

   B. Brief Explanation of Each Process

   C. Attendant Conditions

   D. Total Bond Count - Memoscope Pictures

[redacted]

[redacted]

V. Post-Assembly Treatment

A. Support Attachment

B. Autoclaving

C. Other Treatment

D. Inspection

VI. Pre-Irradiation Examination and Measurements

A. Dimensions, Length, OD, ID

B. Warp

C. Weight

VII. Irradiation

A. Coolant Temperature

1. Inlet
2. Outlet

B. Panellit and Crossheader Pressures

C. Number of Shutdowns (Controlled and Scram)

D. Other

VIII. Post-Irradiation Examination

A. Visual

B. Warp (And Other Profilometer Data)

C. Total Bond Count - Memoscope Pictures

D. Critical Examination of Bond Quality By Stud Pulling and Metallography

IX. Log - Running account with dates recording the progress of the PT, unusual incidents (such as slight change in process during assembly), and other deviations whether or not they seem pertinent at the time of occurrence.

[redacted]

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