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FABRICATION OF HOT DIE SIZED DIFFUSION BONDED FUEL ELEMENTS FOR SUPPLEMENT "A" TO PRODUCTION TEST IP-546-A

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AUTHOR
C. A. Strand

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FABRICATION OF HOT DIE SIZED DIFFUSION BONDED FUEL ELEMENTS FOR SUPPLEMENT "A" TO PRODUCTION TEST IP-546-A

October 5, 1964

By:

C. A. STRAND
Process Development Unit
Fuels Engineering Operation
Production Fuels Section
IRRADIATION PROCESSING DEPARTMENT

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FABRICATION OF HOT DIE SIZED DIFFUSION BONDED FUEL ELEMENTS FOR SUPPLEMENT "A" TO PRODUCTION TEST IP-546-A

INTRODUCTION

Production Test IP-546-A, consisting of 20 charges, for the purpose of irradiating the first hot die sized fuel elements was charged in C-Reactor July 27, 1963. A second test, PT-IP-616-A containing a total of 19 charges had been charged on two separate outages; 13 and 6 tubes on September 28, 1963 and October 30, 1963, respectively. Fabrication of test quantities was becoming more routine and additional irradiation tests were planned. This report summarizes the fabrication of hot die sized fuel elements originally intended for Production Test IP-630-A, but changed to "Supplement 'A' to Production Test IP-546-A, Irradiation of Diffusion Bonded Fuel Elements," HW-75465 E. The production test was changed due to unexpected growth behavior of hot die sized fuel during irradiation.

SUMMARY

Twenty-four (24) charges containing hot die sized and AlSi brazed control fuel elements were prepared for Production Test IP-630-A prior to discharge of the initial hot die size Production Test IP-546-A. Because of the unexpected growth behavior during irradiation of hot die sized fuel, the test was reduced to 10 charges to obtain data on the relationship of the coolant temperature distribution and fuel element behavior* for charging as Supplement A to Production Test IP-546-A. Self-support height was reduced by 0.005 in. to compensate for the anticipated in-reactor dimensional changes. The revised test consisted of five columns of hot die sized fuel elements and five columns of alternating hot die sized and AlSi brazed fuel elements.

Fabrication of the hot die sized fuel elements was routine, and a yield of 71 percent of the pieces plated was achieved.

DISCUSSION

A total of 740 natural uranium cores was selected for the third hot die sizing production test. A yield of 71.1 percent (526 pieces) to autoclaves was obtained. Except for some very slight changes, fuel element fabrication for this test was by the same procedure described in HW-75465 C, "Fabrication of Hot Die Sized

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* HW-75465 E, "Supplement A to Production Test IP-546-A, Irradiation of Diffusion Bonded Fuel Elements," K. L. Hladek, February 4, 1964.

[redacted]

Diffusion Bonded Fuel Elements for Production Test IP-546-A." Exceptions will be noted under separate headings later in the report. Fuel assembly for this test was more routine than in previous tests, making the operation much smoother. A single die was used for all the pieces sized instead of the three used for previous tests. Consequently, dimensional control and end bond die fitting was much improved. During this test, the outer die was used all day without changing, which contributed to an improvement in sizing yield. A summary of all reject categories giving both overall and station reject rates is given in Table I. Process data are recorded in Production Test Notebook, HW-79030.

TABLE I

HOT DIE SIZING REJECT RATES

Number of Pieces Plated 740
Number of Pieces to Autoclave 526 71.08% yield

Tabulation of Rejects

Reject Category	No. Pieces	No. Rejects	Reject Percentage Of Total	Reject Percentage Station Rate
Plating	740	62	8.38	8.38
Assembly	678	0	0	0
Sizing	678	28	3.78	4.13
Trim	650	2	0.27	0.31
End Bonding	648	17	2.30	2.62
UT-4 (Internal)	631	10	1.35	1.58
UT-4 (External)	631	20	2.70	3.17
Welding	601	15	2.03	2.50
Clad Thickness (Internal)	586	9	1.22	1.54
Clad Thickness (External)	586	0	0	0
Bond Integrity (Internal)	586	0	0	0
Bond Integrity (External)	586	0	0	0
End Bond Test (Cap)	586	4	0.54	0.68
End Bond Test (Base)	586	0	0	0
Ultrasonic Welding	573	34	4.59	5.93
Marred Surface	---	13	1.76	----
Total Rejects	---	214	28.92	----

Preparation for Sizing - Component Assembly, Lubrication, and Vacuum Drying

With the exception of component lubrication, all preparations for sizing were the same as described in HW-75465 C. The core-can

assembly was dipped in an Aqua-Dag solution of five parts water to one part Aqua-Dag. Previously, four parts water to one part Aqua-Dag had been used. The thinner solution improved lubrication properties.

Sizing

All sizing conditions were the same except for starting the compressed air quench. Previously, the air was turned on immediately after the piece was sized; however, for this run, the air quench was delayed until the upper ram tip was changed and the carrier halves removed to prevent blowing lubricant fumes in the operator's face. Since then an exhaust system has been installed. This technique also cooled the ram tips faster by conducting the heat from the tip to the chill block rather than conducting up the tip.

Solvent Cleaning

The ultrasonic cleaner filled with Stoddards solvent was used to remove residual lubricant from sized fuel elements prior to end bonding. Previously, the pieces were soaked and wiped, but complete removal was difficult. Ultrasonic cleaning simplified the cleaning somewhat, although it was still necessary to wipe the outside surfaces to remove excessive amounts of lubricant.

Cleaning and Etching

Hot die sized fuel elements were cleaned and etched by the nitric acid, caustic procedure described in HW-75465 C, except that it was done prior to rather than after welding. Results of the first run indicated that inclusions on the fuel surface remained on the weld surface making weld inspection difficult. Removing the inclusions prior to welding greatly simplified weld inspection.

Because fuel elements were cleaned and etched before welding, it was necessary to etch the pieces according to the standard nitric acid etch procedure prior to self-support projection welding.

Self-Support Projection Attachment

Self-support projections were attached to all the fuel elements for this test as described in HW-75465 C. However, after the unexpected growth behavior was recognized, the projection height was reduced by 0.005 in. on the ten charges prepared for Supplement A to Production Test IP-546-A. Self-support projection height dimensional changes are compared below:

	Standard Dimension	Revised Dimension
Support Height (Minimum)	0.082 in.	0.077 in.
Effective O.D. (Maximum)	1.666 in.	1.656 in.

Metallography

Eight fuel elements were sectioned and polished for examination of the diffusion bond. End bonding was more consistent than on the initial "eight-inch" natural uranium. Good bonding was observed on all areas of the fuel elements examined.

Bond Strength

Bond strength measurements by the stud pull technique were made on 31 fuel elements sized for this test. Two 0.190 in. diameter studs were pulled at each of five positions on each piece. Average bond strengths for the five positions are listed in Table II below.

TABLE II

BOND STRENGTH AT FIVE POSITIONS ON HOT DIE SIZE FUEL ELEMENTS

Position No.	Position Location	Pounds Force To Pull 0.190 in. Diameter Stud	Equivalent Tensile Strength (psi)
1	3/4 in. from cap	792.1	26,931
2	1-1/2 in. from cap	606.0	20,604
3	Center	677.4	23,032
4	1-1/2 in. from base	569.8	19,373
5	3/4 in. from base	764.5	25,993
Within position standard deviation		96.0	3,264
Overall average		682.0	23,188
Minimum bond strength expected 1-1/2 in. from base		281.8	9,581
Minimum bond strength observed		360.0	12,240

Preparation of Test Charges and Fuel Element Dimension

Twenty-four weighed and measured charges were originally prepared for continued irradiation testing. However, this test was modified to ten charges after the first hot die size production test, IP-546-A, was discharged. Rail height measurements were also made on the test pieces after the height was reduced as previously described. The ten charges consisted of five columns of hot die sized fuel elements and five columns of alternating hot die sized and AlSi brazed fuel elements.

[redacted]

Weights and measurements of the original 24 columns were submitted to Applied Mathematics, Hanford Laboratories, for analysis. Average measurements ($\bar{x}$) and standard deviations (S) for the HDS and AlSi control fuel elements are listed in Table III* on the following page.

C. A. Strand

Engineer
Process Development Unit
Fuels Engineering Operation

CA Strand:nbh

*Stewart, K. B., Letter to C. A. Strand, "Pre-Irradiation Measurements PT-IP-630-A, A Comparison Between AlSi and Hot Die Sizing Fuel Element Dimensional Characteristics," dated December 13, 1964.

[redacted]

TABLE III

PRE-IRRADIATION MEASUREMENT DATA FOR HOT DIE SIZE AND ALSI CONTROL FUEL ELEMENTS

	AlSi		HDS	
	$\bar{x}$	S	$\bar{x}$	S
Weight (grams)	3680.29	4.032	3982.43	6.297
Length (in.)	8.9320	0.0149	9.0260	0.0106
OD_1 Max (in.)	1.4926	0.00118	1.4904	0.00083
OD_1 Min (in.)	1.4892	0.00120	1.4895	0.00085
OD_1 1/2 (Max + Min)(in.)	1.4909	0.00075	1.4899	0.00078
OD_1 Difference (in.)	0.00324	0.00184	0.00090	0.00065
OD_2 Max (in.)	1.4929	0.00114	1.4902	0.00097
OD_2 Min (in.)	1.4882	0.00112	1.4883	0.00094
OD_2 1/2 (Max + Min)(in.)	1.4905	0.0068	1.4893	0.00075
OD_2 Difference (in.)	0.00467	0.00181	0.00199	0.00118
OD_3 Max (in.)	1.4943	0.00118	1.4911	0.00090
OD_3 Min (in.)	1.4902	1.4893	0.00110	0.00104
OD_3 1/2 (Max + Min)(in.)	1.4922	0.00073	1.4902	0.00085
OD_3 Difference (in.)	0.00411	0.00174	0.00181	0.00096
OD_4 - Warp (in.)	0.00428	0.00170	0.00203	0.00105
ID-5 (in.)	0.37940	0.00052	0.37932	0.00079
ID-6 (in.)	0.38004	0.00068	0.38004	0.00074
ID-7 (in.)	0.38036	0.00056	0.38032	0.00085

OD-1 and ID-5: 1 in. from base end
OD-2 and ID-6: Center of piece
OD-3 and ID-7: 1 in. from cap end

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