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TITLE

FABRICATION OF ENRICHED HOT DIE SIZED DIFFUSION BONDED FUEL ELEMENTS FOR PRODUCTION TEST IP-616-A

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FABRICATION OF ENRICHED HOT DIE SIZED DIFFUSION BONDED FUEL ELEMENTS FOR PRODUCTION TEST IP-616-A

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October 2, 1964

By:

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

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FABRICATION OF ENRICHED HOT DIE SIZED DIFFUSION BONDED FUEL ELEMENTS FOR PRODUCTION TEST IP-616-A

INTRODUCTION

Hot die sizing (HDS) is a process being investigated to replace the existing AlSi brazing process. Hot die sizing consists of sizing a nickel-plated core and aluminum can assembly with cold dies to produce a diffusion bonded aluminum clad fuel element. Upon completion of fabrication of the first natural uranium hot die sized fuel elements for production test IP-546-A, the next step in evaluation of the process was to assemble enriched fuel for further irradiation testing. This report summarizes the fabrication of 0.947% U-235 enriched fuel elements for "Production Test IP-616-A, Irradiation of Enriched Hot Die Sized Diffusion Bonded Fuel Elements," HW-78960.

SUMMARY

Nineteen weighed and measured charges of 0.947% U-235 enriched hot die sized fuel elements were delivered to C-Reactor during September 1963 for irradiation testing. The downstream half of each charge consisted of matched alternating HDS and AlSi brazed control pieces while the upstream half was made up of AlSi brazed fuel.

Fuel elements for this test were fabricated according to the procedure used for the initial eight-inch natural uranium production test except for slight differences in sizing, end-bonding technique, and etching before welding.

DISCUSSION

A total of 560 Model CDB2E, 0.947% U-235 enriched fuel elements was sized for further testing of hot die sized fuel. Cores taken from alternate positions from the HDS rod stock were assembled as AlSi dip-brazed control elements for the HDS fuel. After assembly was complete, 19 reactor test columns of 28 pieces per column were prepared. Matched HDS and AlSi brazed fuel were paired in the downstream half and standard AlSi brazed fuel was used to fill the upstream half of each column. Fabrication of AlSi brazed fuel was normal with the exception of end facing shown in Figure 1 to prevent weld head contact when charging alternate AlSi brazed and HDS fuel. A diagram of the 0.947% U-235 enriched hot die sized fuel is shown in Figure 2.

Hot die sized fuel assembly order and method for the six-inch enriched fuel was the same as described in HW-75465 C, "Fabrication of Hot Die Sized Diffusion Bonded Fuel Elements for Production Test IP-546-A," except for slight changes in sizing, end bonding, and cleaning prior to welding. Exceptions will be discussed under

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appropriate process step headings where changes were made in the original process for eight-inch natural uranium fuel. Process data were recorded in Production Test Notebook HW-81212.

Sizing

The sizing process for six-inch enriched cores was the same as for eight-inch natural cores with one exception. Tests prior to preparing the production test material indicated that the six-inch cores had lower bond strength than eight-inch material. The use of an air quench immediately after sizing to shrink the fuel element before pushing it back through the die was discontinued. Reduction of total heat content of the six-inch core, because of less weight, caused the aluminum nickel interface temperature to drop below the minimum diffusion temperature (350°C) much sooner than for eight-inch fuel. Eliminating the air quench did not introduce any problems in pushing the six-inch pieces back through the die.

End Bonding

Due to less weight involved, end-bonding conditions for the six-inch enriched hot die sized fuel were modified slightly. The overall heating time was reduced. Metallographic examination revealed that the cycle used for eight-inch fuel was not necessary to achieve a good diffusion bond on a six-inch piece. End-bonding process variables used on the resistance heated end bond press for both six-inch and eight-inch models are itemized below for comparison purposes.

TABLE I

SUMMARY OF END-BONDING CONDITIONS FOR SIX-INCH AND EIGHT-INCH HDS FUEL ELEMENTS

	Six-Inch Fuel	Eight-Inch Fuel
Assembly Preheat Time at 680 ± 10C	4-3/4 ± 1/4 min.	5-3/4 ± 1/4 min.
Press Head Temperature	655 ± 5C	655 ± 5C
Press Time	4-1/4 min ± 3 sec.	4-1/2 min ± 10 sec.
Press Head Pressure	4.0 ± 0.25 T/in.^{2}	4.0 ± 0.25 T/in.^{2}

Cleaning and Welding

Difficulties experienced while welding the first production test material were eliminated by cleaning and etching the pieces prior to welding. Surface inclusions in the closure zone remained as inclusions in the weld surface making inspection difficult. Etching the fuel with inhibited caustic removed the inclusions and simplified inspection. Welding technique was the same as for standard eight-inch HDS fuel elements.

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Final Etch

Because the order of processing was changed to etch fuel elements prior to welding, it was necessary to etch them with the standard nitric acid etch after welding to aid inspection and to prepare the surface for self-support projection attachment.

Metallography

Metallographic examination of 17 representative pieces from this run showed very good diffusion bonding. Better end bonding was achieved on this run as evidenced by more complete AlSi wetting of the aluminum cap than on the previous run. Although the end-bonding cycle was reduced for this six-inch material, more heat was applied to the end cap core junction because the AlSi wafer was completely melted in all but one of the samples examined. On the previous run the AlSi wafers were diffusion bonded, but not completely melted.

Bond Strength

External bond strength measurements were taken on 28 HDS fuel elements. The overall average bond strength was 745.2 pounds force to pull a 0.190 inch diameter stud corresponding to a 25,330 psi tensile strength. Average bond strength data for five locations on the six-inch enriched fuel is tabulated below.

TABLE II

BOND STRENGTH OF MODEL CDB2E EXPRESSED AS POUNDS FORCE TO PULL A 0.190 INCH DIAMETER STUD

Location	Average Pounds Force
3/4 in. from cap	705
3-1/2 in. from cap	716
Center	817
1-1/2 in. from base	683
3/4 in. from base	804
Overall Average	745

Preparation of Test Charges and Fuel Element Dimensions

Nineteen weighed and measured charges containing hot die sized and AlSi brazed fuel elements were prepared for in-reactor testing. The downstream half of each charge contained matched and alternating HDS and AlSi brazed fuel. AlSi brazed fuel elements were used for the upstream positions.

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Weights and measurements of the test pieces were submitted to Applied Mathematics, Hanford Laboratories for analysis. Average ($\bar{x}$) and standard deviations (S) for the HDS and AlSi controls are listed below.*

TABLE III

PRE-IRRADIATION MEASUREMENTS OF HOT DIE SIZED AND ALSI BRAZED CONTROL FUEL ELEMENTS

	AlSi		HDS	
	$\bar{x}$	S	$\bar{x}$	S
Weight (grams)	2669.2	4.98	3062.0	5.15
Length (in.)	6.623	0.0180	7.022	0.0089
OD_1 Max (in.)	1.4942	0.00125	1.4931	0.00069
OD_1 Min (in.)	1.4910	0.00123	1.4928	0.00069
OD_2 Max (in.)	1.4947	0.00107	1.4936	0.00099
OD_2 Min (in.)	1.4901	0.00120	1.4925	0.00100
OD_3 Max (in.)	1.4939	0.00115	1.4909	0.00090
OD_3 Min (in.)	1.4899	0.00128	1.4905	0.00083
OD_4 (Warp)(in.)	0.0044	0.00172	0.0014	0.00069
ID_5 (in.)	0.379	0.0007	0.378	0.0007
ID_6 (in.)	0.380	0.0005	0.379	0.0006
ID_7 (in.)	0.380	0.0006	0.3795	0.0006

In general, HDS fuel elements exhibit less variation than AlSi brazed fuel. One exception is the inside diameter where only slight variation is experienced by either process. Warp measurements (D_4) are significantly smaller for HDS canned fuel elements.

C. A. Strand

Engineer
Process Development Unit
Fuels Engineering Operation

CA Strand:nbh

*K. B. Stewart, Letter to C. A. Strand, "Comparisons of AlSi and HDS Pre-Irradiation Dimensional Characteristics," dated October 30, 1963.

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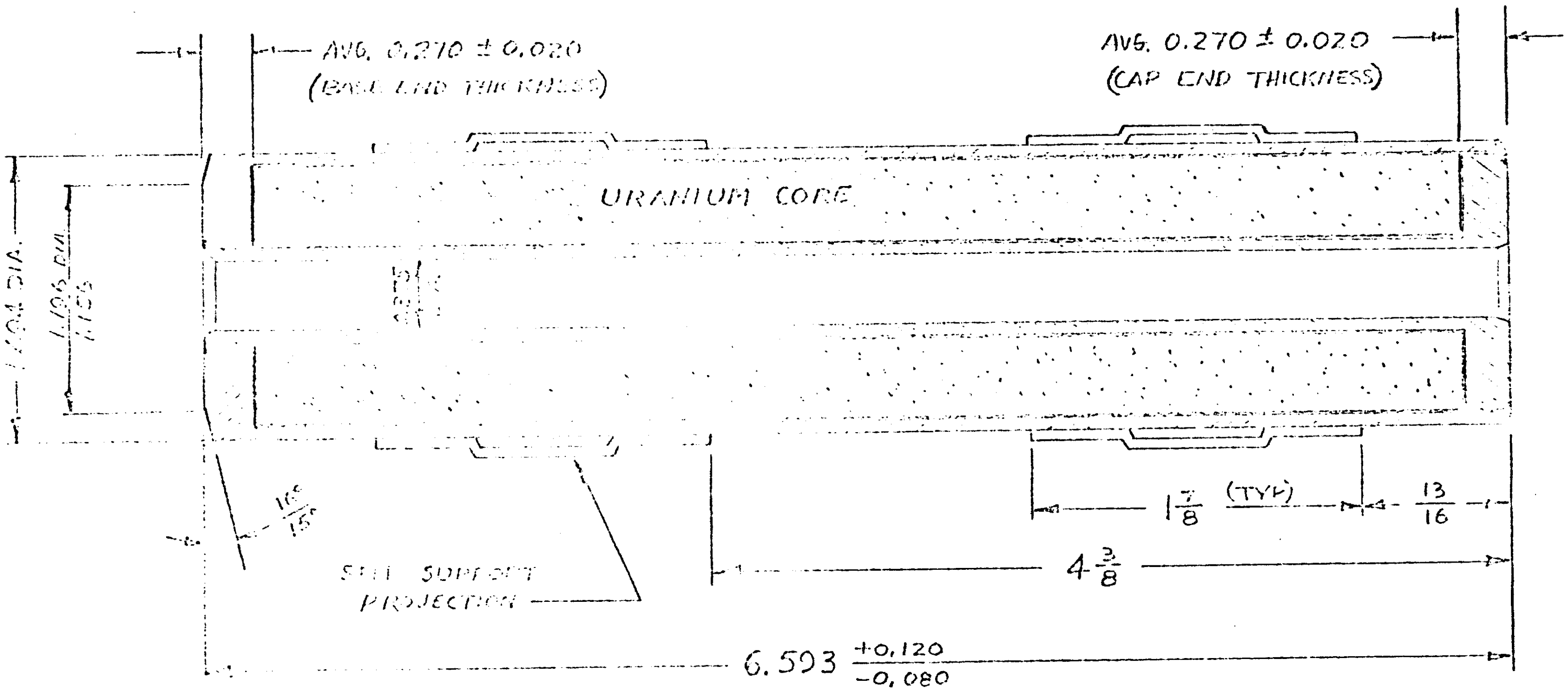

FIGURE I

MODIFIED MODEL C1E ALSI BRAZED FUEL ELEMENT DIMENSIONS

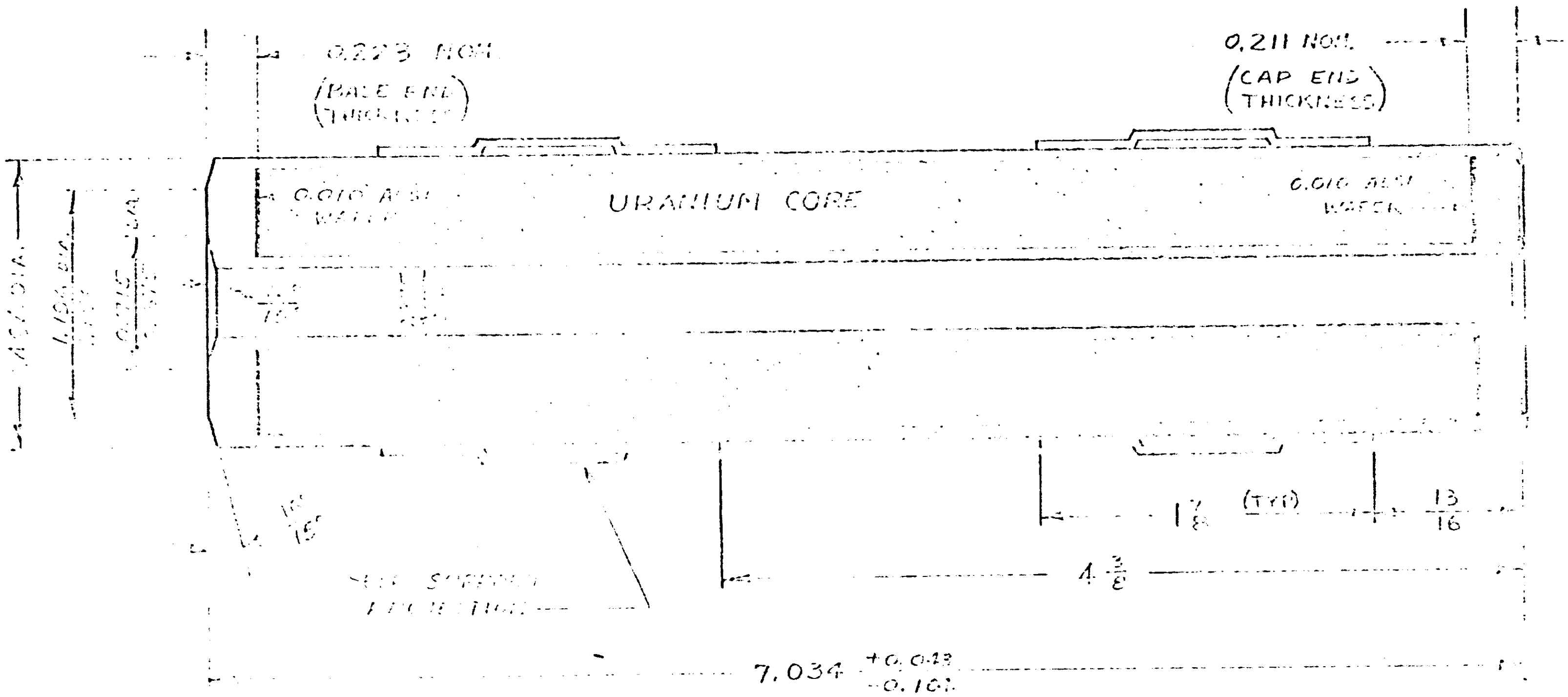

FIGURE 2

MODEL CD32E HOT DIE SIZED FUEL ELEMENT DIMENSIONS

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