DECLASSIFIED

(CLASSIFICATION)

DOCUMENT NO.

HW-83770

SERIES AND COPY NO.

DATE

September 17, 1964

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

THIS DOCUMENT CONTAINS RESTRICTED DATA AS
DEFINED IN THE ATOMIC ENERGY ACT OF 1954.
ITS TRANSMITTAL OR THE DISCLOSURE OF ITS
CONTENTS IN ANY MANNER TO AN UNAUTHORIZED
PERSON IS PROHIBITED.

TITLE

INTERIM REPORT
HIGH-SILICON ALUMINUM CLADDING FOR
HOT DIE SIZED FUEL ELEMENTS

OTHER OFFICIAL CLASSIFIED INFORMATION

THIS MATERIAL CONTAINS INFORMATION AFFECTING
THE NATIONAL DEFENSE OF THE UNITED STATES
WITHIN THE MEANING OF THE ESPIONAGE LAWS,
TITLE 18, U.S.C., SECS. 793 AND 794, THE TRANS-
MISSION OR REVELATION OF WHICH IN ANY MANNER
TO AN UNAUTHORIZED PERSON IS PROHIBITED BY
LAW.

AUTHOR

C. A. Strand

CIRCULATING COPY

RECEIVED 300 AREA

OCT 2 1964

RETURN TO

TECHNICAL INFORMATION FILES

THIS DOCUMENT MUST NOT BE LEFT UNATTENDED OR WHERE AN UNAUTHORIZED PERSON MAY HAVE ACCESS
TO IT. WHEN NOT IN USE, IT MUST BE KEPT IN AN APPROVED LOCKED CONTAINER WITHIN AN APPROVED
GUARDED AREA. WHILE IN POSSESSION AND WHILE YOU HAVE OBTAINED A SIGNATURE FROM
CLASSIFIED FILES, IT IS YOUR RESPONSIBILITY TO KEEP IT AND ITS CONTENTS WITHIN THE LIMITS OF
THIS PROJECT AND NOT TO REVEAL IT TO ANY UNAUTHORIZED PERSON. IT IS NOT TO BE REPRODUCED, COPIED,
OF RESIDENTS IS PROHIBITED. IT IS NOT TO BE REPRODUCED. ADDITIONAL INFORMATION IS REQUESTED,
OBTAINED FROM THE RELATED ISSUES. PERSONS READING THIS DOCUMENT ARE REQUESTED
TO SIGN IN THE SPACE PROVIDED BELOW.

ROUTE TO:

PAYROLL NO.

LOCATION

FILES ROUTE
DATE

SIGNATURE AND DATE

J. W. Ambrose

16289

1760D Bldg.

10-26-64

10/21/64

DECLASSIFIED

MASTER

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DECLASSIFIED

HW-83770

This document consists of
9 pages.

A

INTERIM REPORT
HIGH-SILICON ALUMINUM CLADDING FOR
HOT DIE SIZED FUEL ELEMENTS

by

CLASSIFICATION CANCELLED

Per DOC, May 1973

By B. Roberts 1/30/74

C. A. STRAND

Process Development Unit
Fuels Engineering Operation
Production Fuels Section

IRRADIATION PROCESSING DEPARTMENT

September 17, 1964

DISTRIBUTION

1. TW Ambrose	13. HC Money-JD Schaffer
2. RE Baars	14. DE Munro
3. HE Berg	15. EV Padgett
4. WA Blanton	16. DW Peterson
5. HC Bowen-RL Dillon	17. GM Schweikhardt
6. LA Conner	18. CA Strand
7. SM Graves	19. JT Stringer
8. KL Hladek	20. HF Tew
9. GA Huff	21. VP Thomas
10. OB Isaacs	22. Records Center
11. GF Jacky	23. 300 Area Files
12. J. T. Knight	

Classification Cancelled and Changed To

DECLASSIFIED

By Authority of R M. Olen

PR-24, 4-11-94

By J E Savely 4-16-94

Verified By Gerri Moley 4-18-94

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

INTERIM REPORT
HIGH-SILICON ALUMINUM CLADDING FOR
HOT DIE SIZED FUEL ELEMENTS

INTRODUCTION

Results of literature searches of other development work, both local and foreign, concerning improved fuel element jacketing materials, has revealed that high silicon aluminum alloys show some promise⁽¹⁾. According to Videm⁽²⁾, aluminum alloys having over 5 percent silicon along with 1 percent nickel, and 0.3 percent iron had superior corrosion resistance than 8001 aluminum alloy in 230°C and 265°C water. Concurrent with a local literature search⁽¹⁾, development of a low-melting aluminum alloy wafer to simplify end bonding of hot die sized fuel was underway. Although a 10 percent silicon-aluminum alloy wafer was not considered a low-melting alloy, it was tried for initial development purposes. Metallographic examination of the test pieces indicated that the 10 percent Si-aluminum wafer bonded to electronickel plate more readily than 8001 aluminum alloy. Considerable experience with diffusion bonding of 10 percent Si-aluminum alloy to nickel-plated cores has been gained because AlSi wafers have been used to act as a secondary barrier on fuel ends in the event of closure failure of hot die sized elements⁽³⁾⁽⁴⁾.

Because of an anticipated need for fuel having improved cladding corrosion resistance to withstand more severe reactor service, the favorable experience with diffusion bonding of high-silicon alloy to nickel, and the versatility of the hot die sizing process, an investigation of high-silicon alloys as a fuel element cladding material was begun here at Hanford. This report summarizes the work carried out to date with four high-silicon alloys produced for cladding fuel by the hot die sizing process.

SUMMARY

A tentative process for fabricating high-silicon alloy hot die sized fuel elements has been established. Good diffusion bonding has been produced at lower temperatures than used for the standard hot die sizing process using 8001 aluminum alloy. Fabrication of pieces for irradiation testing was deferred due to inconclusive results of initial corrosion tests. Corrosion testing is continuing.

DISCUSSION

According to a local literature search⁽¹⁾ and results of experimental work by Videm⁽²⁾, use of high-silicon aluminum alloys displayed improved corrosion resistance over 8001 aluminum alloy. Because of a potential need for driver fuel elements having improved corrosion resistance for possible future isotope production and the fact that high-silicon aluminum diffusion bonds to electronickel plated cores readily, a decision was made to initiate development tests with similar

alloys. Videm's work tested a modified 8001 alloy which contained silicon and magnesium. Aluminum alloy 8001 normally has a nominal 1 percent nickel, 0.5 percent iron, and less than 0.2 percent silicon. Examination of the compositions of the various test alloys raised the following questions with regard to in-reactor corrosion resistance, component fabrication and fuel fabrication by the hot die sizing process.

1. What silicon concentration would be best with regard to corrosion, component formability, and fuel fabrication? (Videm's work suggested that alloys containing 10 percent silicon had the best corrosion resistance. From the workability standpoint, 6 percent Si had the best properties.)
2. What effect does nickel have on the corrosion resistance of a high-silicon aluminum alloy?
3. What effect does magnesium have upon the corrosion resistance and workability of a high-silicon aluminum alloy. (Magnesium was added to Videm's experimental alloys to improve fuel element jacket mechanical properties.)

Because of the need for information to answer the above questions, four high-silicon alloys were proposed for initial development work. Nominal compositions of the four alloy types selected are listed below:

TABLE I
COMPOSITIONS OF HIGH-SILICON ALLOYS FOR
HOT DIE SIZING DEVELOPMENT WORK

<u>Alloy Designation</u>	<u>Alloying Element</u>			
	<u>Silicon</u>	<u>Magnesium</u>	<u>Nickel</u>	<u>Iron</u>
HDA1	10%	1%	1%	0.5%
HDA2	6%	1%	1%	0.5%
HDA3	10%	1%	None	0.5%
HDA4	10%	None	1%	0.5%

Alloys HDA1 and 2 are similar to that used for Videm's work and were obtained to determine the effect of silicon upon ease of fabrication and corrosion resistance. Alloy HDA3 was obtained to determine the need of nickel for corrosion resistance of high-silicon aluminum alloys. The fourth alloy was picked to determine the effect of magnesium upon corrosion resistance and fabrication.

At the time procurement of high-silicon alloys from commercial producers was initiated, samples of alloys HDA2 and 4 were produced on site for testing. Internal tubing was extruded from billets cast from the two alloys and used for initial sizing tests. End caps were also made by machining from cast billets. Test quantities

of fuel elements clad with high-silicon inner tubes and high-silicon cap and base ends in combination with a standard 8001 alloy outer tube were sized. Bonding between the Hanford produced high-silicon alloys and the electronic nickel plate was good. As a matter of interest, the high silicon end caps bonded to both the high-silicon inner tube and the 8001 alloy outer tube without the end bond step. There was no bonding between the core end and cap.

Corrosion testing of both Hanford and Alcoa produced high-silicon alloys was started as soon as representative samples became available. Results of initial tests are inconclusive, and corrosion testing is continuing.

Process Development work consisted of testing the following process steps for producing hot die sized fuel clad with high-silicon alloy:

1. Tube cut off and forming
2. Component cleaning
3. Sizing
4. Trim
5. End Bonding
6. Facing
7. Welding
8. Etch

Each of the process steps will be discussed briefly under their individual headings.

Tube Cut Off and Forming

High-silicon aluminum alloy tubing was cut in 10-1/2 inch lengths and formed the same as standard 8001 tubing. Some difficulty in flaring the inner tube was experienced when the tubing cracked before flaring. Alloy HDA4 was the easiest to handle at this step.

Component Cleaning

A caustic etch procedure was used for cleaning high-silicon aluminum components for initial sizing tests. Because of the tendency for a slight deposit of black smut, use of a nitric-hydrofluoric acid etch was also tested. Cleaning procedures⁽⁵⁾ used for initial sizing tests are listed below:

Procedure A:

1. Caustic etch: Turco 4181-19, 2 to 3 oz/gal, 70 to 75°C
2 to 2-1/2 min.
2. Hot water rinse (50°C)
3. Cold water rinse
4. Desmut - Diversy 514, 16 oz/gal, Room temperature,
5 to 10 min.
5. Cold water rinse
6. Hot air dry

Procedure B:

1. Caustic etch: Turco 4181-19, 2 to 3 oz/gal, 70 to 75°C, 2 to 2-1/2 min.
2. Hot water rinse (50°C)
3. Cold water rinse
4. Nitric-hydrofluoric acid: 5 to 7M. HNO_3 and 2 to 3M. HF, 20 to 30 sec.
5. Cold water rinse
6. Desmut - Diversey 514, 16 oz/gal, Room temperature, 5 to 10 min.
7. Cold water rinse
8. Hot air dry

Use of nitric-hydrofluoric acid brightened the surface, but also left a heavier smut deposit as detected by wiping with a clean white cloth. No bonding evaluation was made of the two procedures because the cleanliness of cores for the first test was questionable. Procedure "A" was used for the second test because it was much simpler and the cleaning appeared superior. Good bonding was obtained.

Sizing

Sizing fuel elements assembled with high-silicon alloy components was similar to sizing with 8001 alloy components except that preheat time was slightly reduced. Preheat times used were from 10 to 12 minutes, which would be equivalent to 12 to 14 minutes for 8001 alloy cladding. All other conditions were identical to those used for conventional sizing. Sizing conditions used are itemized below:

TABLE II

SUMMARY OF CONDITIONS USED FOR HOT DIE SIZING
WITH HIGH-SILICON ALUMINUM ALLOYS

Preheat Furnace Temperature	680°C
Preheat Time	10 to 12 min
Ram Speed	65 in./min
Wall Reduction	45.5%
Carriers Used	Yes

Trim

The trimming operation was the same as for standard hot die sized fuel. High-silicon alloy cladding was considerably harder than 8001 alloy which required a slightly different facing technique. Facing tool life is expected to be shorter.

End Bonding

Initial end bonding of high-silicon alloys was accomplished by merely changing the end bond press temperature set points by the difference between the silicon alloy and the 8001 alloy melting points ($\sim 65^{\circ}\text{C}$). End bond pressure and time were the same as used for standard hot die sized fuel at that time. The motor-generator unit power setting was reduced to give the desired end temperature in the standard time. End-bonding conditions are itemized below, along with those used for standard hot die sized fuel for comparison purposes.

TABLE III

COMPARISON OF END-BONDING CONDITIONS FOR HOT DIE SIZED FUEL CLAD WITH HIGH-SILICON AND 8001 ALUMINUM ALLOYS

	<u>Cladding Alloy</u>	
	<u>High Silicon Alloy</u>	<u>8001 Alloy</u>
Head temperature setting	685°C	750°C
Pressure	4T/in. ²	4T/in. ²
Power setting	6KW	10KW
Power time	1 min 30 sec	1 min 30 sec
Total press time	3 min 10 sec	3 min 10 sec

Recent work with end-bonding and induction-heating equipment has enabled a reduction of both the power time and the total press time for 8001 alloy clad fuels. A corresponding reduction is expected for end bonding high-silicon clad fuel elements.

Fuel Element Etch

A tentative process for cleaning high-silicon clad fuel elements prior to welding consisted of the following nitric acid and caustic etch method.

1. Nitric acid: 80°C for 10 min.
2. Flowing process water rinse
3. Caustic etch: Turco 4181-19, 2 oz/gal, 70°C, 1 min.
4. Flowing process water rinse
5. Deoxidize: Diversey 514, 16 oz/gal
6. Process water rinse

This technique left a slight smut which can be removed by modification of the above, either by adding a nitric-hydrofluoric acid desmut or using a process similar to that for component cleaning.

Welding

Except for amperage, high-silicon alloy clad fuels were welded by the tungsten inert gas shielded welding method as is 8001 alloy

aluminum. The inert gas shield consisted of a mixture of 95 percent helium and 5 percent argon. A turntable speed of 20 rpm was used. Inner and outer welder amperage for both high-silicon and 8001 aluminum alloys are listed below.

	Aluminum Alloy	
	High Silicon	8001
Outer Weld Amperage	140 min.	115 min.
Inner Weld Amperage	125 min.	50 min.

High-silicon alloy HDA4 appeared to be the easiest to weld initially. There was not much difference in the weldability of the four alloys in later tests.

Metallography

Samples of hot die sized fuel elements clad with high-silicon alloy have been sectioned and polished for metallographic examination of the nickel-AlSi diffusion bond. AlSi-nickel diffusion on the inner and outer surfaces was extremely thin, which is characteristic of a good diffusion bond. Evidence of good bonding included (1) lack of tearing at the sample edges due to sample cutoff, and (2) very thin strips of cladding remained bonded to uranium when cuts were made 1/16 inch apart. Peel tests also indicated strong bonding. No bond strength measurements by the stud pull method have been made. Nickel-AlSi diffusion on the ends as produced by previously mentioned end-bonding conditions, was pronounced. On the basis of observed thick diffusion (~ 0.1 mil) on the ends, lower temperature and time combinations could be used to produce satisfactory end bonding. Examples of high-silicon aluminum to nickel diffusion bonds are shown in Figure 1.

C. A. Strand

Engineer
Process Development Unit
Fuels Engineering Operation

CA Strand:nbh

DECLASSIFIED

- 8 -

HW-83770

CONFIDENTIAL

REFERENCES

1. Knight, F. W., Personal Communication, August 1963.
2. Videm, Ketil, Aluminum Alloys with Improved Corrosion Resistance in High Temperature Water, KR-19, May 1962.
3. HW-78869, "End Closure of Hot Die Sized Diffusion Bonded Fuel Elements," C. A. Strand, January 14, 1964.
4. HW-75465C, "Fabrication of Hot Die Sized Diffusion Bonded Fuel Elements for Production Test IP-546-A," C. A. Strand, October 10, 1963.
5. HW-71194, "304 Building Logbook," pp. 84-87, June 1964, G. F. Jacky.

UNCLASSIFIED

-9-

HW-83770

High-Silicon Aluminum
Alloy HDA-1

AlSi-Ni Diffusion
Nickel Plate

Uranium

Alloy HDA-2

Alloy HDA-3

Alloy HDA-4

500X

FIGURE 1

Typical AlSi-Nickel Diffusion Produced by End Bonding Four High-Silicon Aluminum Alloys

UNCLASSIFIED